The
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UNIVERSITY OF MICHIGAN

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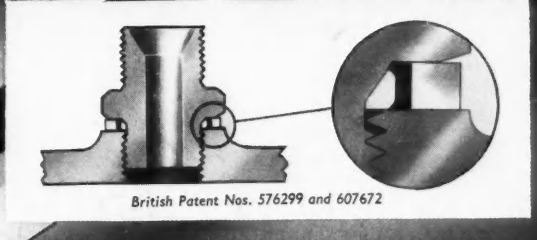

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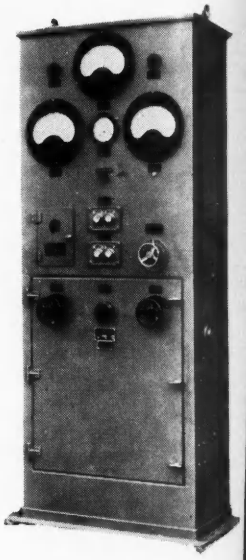

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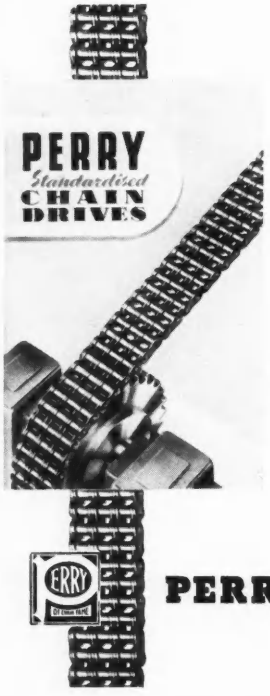

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *CARBON DIOXIDE COOLANT*

The employment of carbon dioxide as coolant in carbide tool grinding is reported to have fully proved its usefulness in extensive shop tests. Its advantages have been found to be many, such as cleaner grinding conditions, handling of carbide tools in a cool state and at room temperature, elimination of disposal problems, and controlled coolant temperature. The direct monetary savings accruing from the application of this coolant are due to faster grinding, increased efficiency, and a direct reduction in the amount of carbide tool cracking due to grinding. Unlike other coolants, carbon dioxide permits a positive temperature and pressure control to be effected so that the temperature can be controlled at a point where the danger of cracking from thermal stress is precluded. With regard to grinding wheel life, it has been found that a reduction in wheel consumption in carbide grinding is obtained owing to the absence of excessive heat, so that the abraded material is prevented from fusing into the grinding wheel. Moreover, in rough grinding tests it has been found possible to remove stock faster with a better finish. On the other hand, for finish grinding, the use of carbon dioxide coolant with diamond wheels offers the advantage that many tasks can be carried out within a shorter time, yet with a sharp reduction in wheel disintegration despite heavier feeds. It goes without saying that the use of carbon dioxide as coolant completely eliminates any fire hazard. A serious drawback is, however, the relatively high cost of carbon dioxide as compared with conventional liquid coolants, and this makes it imperative that due precaution against waste should be exercised.

● *IMPROVED STEEL QUALITY BY COLD FORMING*

It has always been known that by proper application of cold working, a considerable improvement in the properties of a given steel can be effected. For the production of high-quality steel to be used for precision screws and components for use in precision mechanisms, a special steel processing routine has been evolved which is claimed to result in the production of carbon steel rods of exceptionally high quality. When starting, for example, from wire of 14 mm diameter, care is taken to employ a material of fine crystalline structure with uniform distribution of the cementite in globular form. After descaling the material, it is first passed through a draw bench, where a slight reduction in diameter is combined with an improvement in surface quality. The straightened rounds are next passed into a rotary swage of special design, in which the material is subjected to a squeezing process of high frequency, ranging from 2,000 to 3,000 compression cycles per minute. This high-frequency squeezing effect produces a plastic deformation in depth, and at the same time a slight reduction in diameter. In order to eliminate the strain hardening caused by this treatment, the material is then subjected to an anneal which is carried out by induction heating with a frequency of 10,000 cps. This treatment will, of course, produce a considerable increase in tensile strength and, when repeated, will produce further increases in strength until the material has attained its maximum strength. Final processing of the rounds consists in straightening and surface grinding to a diameter tolerance of 0·00008 in. The inventor of the process considers the effects of the squeezing process upon the material to be purely mechanical in character, but this theory has not been verified as yet.

● *USING EXHAUST GASES OF ENAMEL COATING OVENS*

It is reported that the successful pilot operation of catalytic agents as a means of re-using the gases normally exhausted in the enamel coating of metals may open up a whole new field of application for these oxidising agents. This report is based upon the experience gained by a large user of enamelling ovens who investigated the use of a catalyst for the recovery of heat from the oven-exhaust discharged to atmosphere. In the operation of the plant referred to, gas burners are turned on initially to raise the temperature in the oven to the required level. As the enamel is baked dry in a continuous process, the solvent fumes are exhausted into a stack and pass over the catalytic elements. Heat thus generated in the catalyst is returned to the oven by means of an airheater, so that the gas burners can be turned off and the operation becomes self-supporting. Batteries of the catalytic units are made of coated porcelain rods of 5½ in. length which are placed in the venting stack. The catalytic unit itself is made up of two porcelain end plates, a spacer bar of porcelain and the requisite number of coated porcelain rods. The end plates are joined rigidly

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at their centres by the space bar after the rods have been inserted at both ends in shallow sockets in the plates. There is some play in the rods in order to allow for expansion and contraction during temperature changes. The rods are assembled in staggered rows and are streamlined to ensure good contact with the gases and to offer minimum flow resistance to the passage of the fumes through the catalytic unit. The vital part of the unit is the coating of 0·003 in. thickness covering the rods. This is a film of catalytic alumina and platinum alloy applied by a special process. It is claimed that in this way as much as 90 per cent of the previous gas consumption can be saved.

● *NEW PLASTIC MATERIAL*

The fluorocarbon-type plastics recently introduced are claimed to possess extraordinary resistance to heat, moisture, and chemical action. With regard to the latter, no attack has been observed under prolonged exposure to concentrated sulphuric, hydrofluoric, and hydrochloric acids, to strong caustic, to fuming nitric acid, aqua regia, and other vigorously oxidising media. The material is claimed to be equally resistant to most organic solvents. With regard to its electrical properties, the material is reported to have electrical properties superior to most plastics. It possesses a high electrical resistance and its dielectric constant is stated to be in the range of the best available materials. Its thermal conductivity is low, and its properties are generally satisfactory over a temperature range extending from minus 320° F, corresponding to the temperature of liquid nitrogen, to an upper ceiling temperature of 390° F. The results of continuous moisture absorption tests have shown this plastic to possess zero water absorption. An unusual property is the material's exceptional resistance to wetting by water; it is also unaffected by high humidity and tropical exposure. Fabricating characteristics are said to be good; the material can be moulded by compression, transfer, injection and extrusion. It can be readily punched, drilled or otherwise machined to close tolerances. Typical applications in which the material has already proved its value are valve diaphragms, valve seats, gaskets, packing rings, coated wire, rotary electric switches, etc. In complicated bases for electronic valves, the material combines mechanical strength with the ability to be injection-formed in a most complicated mould, and to produce at the same time a hermetic seal between metal and plastic base.

● *TITANIUM COATING OF CERAMICS*

A novel method makes it possible to produce a titanium coating on a silica-containing ceramic. This process is of particular importance insofar as nearly all high-voltage electrical insulators must be joined to metal fittings. A common method, such as is used in the manufacture of suspension insulators, employs Portland cement for making the joints. A low-melting alloy is also sometimes used for the same purpose. The new method employs the phenomenon that if a silica-containing, glazed ceramic is immersed in a bath of one or more alkali or alkaline earth halides and divalent titanium, a coating of titanium is formed on the surface of the immersed article; the thickness of this coating increases with the time of immersion. The container in which the bath is prepared must be able to withstand operating temperatures approximating to 1,000° F and to resist any large-scale reaction with the titanium or with the halide salts. For this purpose, glass containers or carbon crucibles have proved very satisfactory, but iron or other metals may also be used as container material. Ceramic containers are not suitable for external heating as they are porous enough to allow the salt bath to pass through the walls of the container. However, if the bath is heated by internal electrodes and cooled on the outside, a solid salt crust will form on the interior walls and prevent the fused salt bath from leaking out. The divalent titanium may be introduced into the fused salt bath in several different ways, as, for instance, by electrolysing the bath by passing a direct current between a titanium anode and a titanium cathode.

● *INVESTMENT CASTING OF ALUMINIUM*

The investment casting of aluminium-base alloys requires certain changes in the technique used for copper-base alloys. It is well known that the properties of cast aluminium alloys are quite sensitive to the rate of freezing. This indicates the desirability of using low mould temperatures and minimum pouring temperatures. The use of low mould temperatures with the standard dry investment, however, results in the disadvantage that there it creates a tendency for cracks to develop in the mould. These cracks are generally caused by the contraction stresses, which accompany the lowering of the mould temperature from the point at which the wax residue is eliminated. It was found that, in order to avoid cracking, a reduction in burn-out temperature is desirable. By heating invested moulds in an atmosphere saturated with water vapour, an equilibrium condition is established between the moisture in the atmosphere and that in the mould, so that the latter is kept saturated with sufficient water to prevent the capillaries from forming. In order to facilitate further the removal of wax, the melt-out temperature is raised by performing the operation in an autoclave with superheated steam at 15 psi pressure. With moulds prepared under these conditions, it is possible to complete the final burn-out operation at 600° F for 24 hours or 800° F for 2 hours. When these moulds are cooled to the proper temperature for casting, cracking in most

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instances will be avoided entirely, or at least be confined to very small hairline cracks. Sodium modification improves the ductility of the alloy considerably, and it is reported that a small addition of sodium metal made to the melt before pouring will increase the elongation to approximately twice the original value.

● *NEW FABRICATION TECHNIQUES FOR MAGNESIUM*

With the recent improvements achieved in magnesium die casting techniques, an opportunity arises for designers to utilise more fully the advantages of the versatile characteristics of this metal. Its low weight, ready availability, and good workability are qualities which should increase the prospect of magnesium ultimately becoming a common structural metal. The recent expansion in the use of magnesium for light-weight welded assemblies is largely due to two factors. Firstly, the welding characteristics of magnesium make arc and spot welding of all types of joints a simple and economical proposition. Secondly, the joint strength efficiencies for the material are high, ranging as they do to over 90 per cent. Its good machining characteristics are another factor which favours the employment of magnesium in many designs. Thus, it is by no means unusual that, by changing from cast iron to magnesium, machining time can be reduced by as much as 70 per cent. Cutting tool life is likewise very favourably affected when changing over to magnesium. Based on identical unit weight, the bulk of magnesium is approximately 4½ times that of a ferrous metal, and approximately 50 per cent more than that of aluminium. Practical experience indicates that a general rule to follow in changing over from iron to magnesium as construction material, is that approximately twice as much magnesium is required to replace steel, so that the use of magnesium results in a weight saving of approximately one-half as compared with the use of steel. For the impact extrusion of magnesium tool steel or carbide dies are used which will give a service life estimated at 200,000 and 10,000,000 parts respectively. Close tolerances may be obtained by careful alignment of tools, the use of short punches, and small clearances between the slug and the die.

● *CEMENTED CARBIDE TOOL CHARACTERISTICS*

An investigation of the machining characteristics of nodular cast iron has brought forth extremely interesting information on the relation between tool-chip adherence and the grade of cemented-carbide tool used. Flank adhesion tests conducted with cemented carbide tools containing titanium carbide showed that a temporary build-up occurred during cutting, while the temperature at the cutting point remained below that of titanium oxide formation. But when the additional flank friction had raised the temperature sufficiently to cause oxidation to titanium-oxide, the adhering flank build-up was swept away. This observation, therefore, confirms earlier concepts of a theory which postulates that the superior cutting performance of carbides containing titanium carbide can be ascribed to the formation of a titanium-oxide film between tool surface and chip. This action is apparently another example of the chemical functioning of a cutting fluid to reduce friction and adhesion by the formation of a low-shear-strength solid film at the interface between tool and work material. In this case the cutting fluid is the oxygen of the air, and it reacts with the titanium carbide in the tool material, under the action of the high temperatures and pressures existing at the sliding surfaces, to form a relatively low-shear-strength film of titanium oxide at that interface, thereby reducing metal-to-metal contact, adhesion and friction. In the more common types of cutting fluid action, the fluid is usually a liquid and one or more of the chemical additives contained in it reacts with the work material at the tool interface to form a low-friction film.

● *LARGE-SCALE FUEL CELL PLANT*

According to a recent report, the large-scale installation of a fuel cell installation for the direct conversion of coal into electrical energy is under consideration. The new method will completely eliminate the use of boilers and steam turbines. Carbon is heated in the presence of steam, producing a mixture of carbon monoxide and hydrogen. This gas then flows over the cathode of the cell, and picks up oxygen. This causes more oxygen to flow through the electrolyte from the anode; it is supplied by air flowing over it. The cell action produces an e.m.f. of 0·07 to 0·09 volt, and the current is dependent on the electrode area. A series arrangement will be used to increase the voltage. Any form of carbon can be used, but the best form is believed to be a reactive type such as is provided by the low-temperature carbonisation of coal. Both electrodes consist of a porous mixture of iron and iron oxide. The electrolyte is described as a refractory-type material which must contain some rare earth elements such as cerium or thorium. The anode is of such a composition that, in relation to the cell itself, oxygen combining to form iron oxide as it passes over the cell brings about various chemical changes which result in the release of energy. The gasification process requires heat, while the fuel cell itself gives off heat, and once started there is enough heat to maintain the process. For this reason the fuel cell is placed inside the gasification chamber. Hot gases are used to preheat water for the steam-carbon reaction. This recycling of heat energy is expected to result in an efficiency of nearly 80 per cent. There is no doubt that long-range experimentation will be required to bring this plan to fruition.

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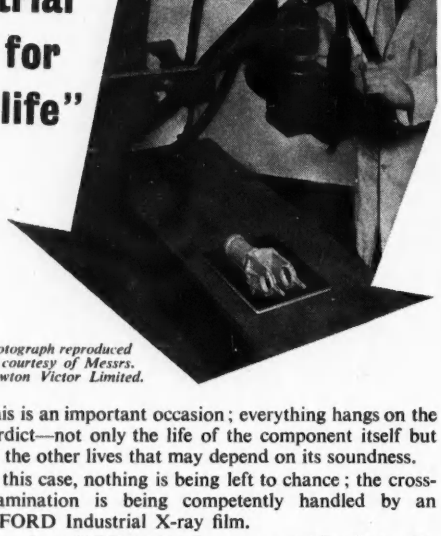

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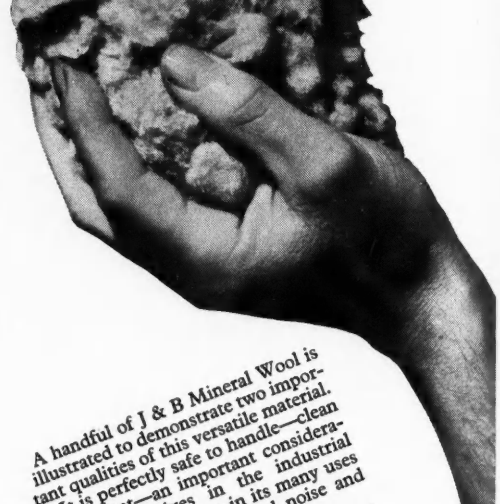

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• *NEW REFRACTORY FIBRE*

It has been found that by subjecting a molten stream of aluminium oxide, silica and certain modifying agents to a controlled blast of air, a ceramic fibre can be produced which should find many applications in industry. The new fibre resists temperatures which melt cast iron, yet its fineness is such that it can be used as a superfilter, as well as a base for entirely new types of insulation and fireproof and electrical papers. The development of the new fibre took its inception from the investigation of alumina bubbles which are used extensively as insulation in high-temperature commercial applications. These bubbles are made by blasting molten alumina with air. In carrying out this process, it was noted that the occasional formation of fibres took place. By experimenting with alumina and silica, and developing modifying agents, and by extensive experimentation with various air blast pressures at different temperatures, it was found possible to carry the blowing process beyond the bubble stage and, in effect, to blow each bubble into a fine fibre. Basically, the new product is a vitreous ceramic rather than crystalline. Relatively rapid cooling from the melt provides the fibres with a smooth vitreous surface and long length, and may also account for their resilience. The new material can be used immediately, in combination with, or as a replacement for, asbestos in many applications. The fibre retains all its properties at temperatures up to 2300° F and does not soften at temperatures approaching 3000° F. The material is already finding application as high-temperature insulation in the combustion and exhaust systems of jet engines.

• *DIFFUSION-TREATED GAS TURBINE BLADING*

It has been observed that drop-forged articles made of usual specification steels can be treated in conventional manner by metallic diffusion processes as, for instance, chromising, but tend to develop surface cracks on cooling. This is mainly due to the effect of the diffusing metal acting on the already high forging stresses of the material. The same effect is also noticeable on parts which have been subjected to heavy machining or polishing, and which have thus acquired high surface stresses. It has now been found that, in order successfully to apply a thermal diffusion treatment to such parts, it is necessary to relieve the internal stresses as a preliminary step. This can be effected by a stress-relieving annealing or full annealing, or even normalising treatment. When such treatment has been carried out prior to metallic diffusion, no surface cracks are found in the coating, which is as sound as the diffusion layer obtained on normally machined articles. This invention may be applied in the manufacture of compressor or gas turbine blades. These can be produced by forging them from low carbon steel and then subjecting them to an annealing or normalising treatment which relieves the internal stresses, these being particularly high in the trailing edge of the blade. The blades are then subjected to the thermal diffusion treatment, and, where necessary, may receive a final coining treatment under pressure in a shaping die. In this way compressor blades have been forged from 0·15 per cent carbon steel, machined to size, annealed by heating at 920° C and then treated by a chromium diffusion process at 1100° C for 4 hours, producing a chromium layer of some 0·005 in. thickness.

• *POWDER METALLURGY APPLIED TO BATTERY PRODUCTION*

Considering alkaline storage batteries, the nickel-cadmium battery differs from the nickel-iron battery with respect to the negative active materials and certain constructional details. Both types utilise perforated steel pockets or tubes for enclosing the active materials, thus eliminating the problem of shedding. The use of porous sintered carbonyl iron and sintered carbonyl nickel plates for alkaline batteries is a relatively recent development. The sintered plate battery differs from the conventional battery in that it has porous nickel plates which serve as retainers of the active material and as collectors and conductors of the current to the cell terminals. The plaques are prepared by sintering carbonyl nickel powder and are usually made in graphite moulds simply by filling the mould cavity with powder without the application of compacting pressure as is common in powder metallurgical practice. A grid, which usually is made of commercially pure nickel wire cloth is packed at about the middle of the powder in order to confer strength, to control the thickness and to eliminate distortion. The sintering is carried out for about 10 minutes at 1600 to 1700° F in a dissociated ammonia atmosphere, and the cooling of the plaque and mould is usually carried out in the same atmosphere. The plaques have a porosity of 75 to 80 per cent, of which about 40 to 50 per cent is utilised to retain the active material introduced into the pores by an impregnation process. This process, which is used for both the positive and negative plates, consists of immersing the plaques in nickel or cadmium salt solution, polarising cathodically in alkali solution, washing and drying. This cycle of treatment is repeated until the desired amount of nickel or cadmium hydroxide has been deposited in the pores of the plates.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.

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Olympia and Hanover

Two International Machine Tool Exhibitions recently took place at practically the same time, showing the latest products of Continental Europe, Great Britain and America, with the significant difference that British machine tools were not shown at Hanover, but almost all important European, including a few American, machine tools were seen in London.

The Chairman of the European Committee responsible for the Hanover exhibition explained (at a Press conference) that both exhibitions were not competitive and to accept his explanation seems to be the best way out of the delicate position created by the abstention of the British Machine Tool Trades Association from participation in the European venture. It is to be hoped that some day in the future British machine tools will be seen on the same floor with all other European competitors.

The European show was immense not only in floor coverage but also in the size of some of the machines shown. Besides being impressed by giant machine tools, all visitors were struck by the enormous choice in modern machine tools of practically the same standard and performance, such as centre lathes, milling machines, shapers, cylindrical grinders, surface grinders, etc. It appears reasonable to assume that for the average user there were about 20 machines of the same type, size, and design characteristics from which to make his selection. It becomes quite obvious that a selection under such circumstances cannot be influenced by fundamental characteristics, but will be decided more by other factors, among which price is probably not unimportant. It is quite clear that the consequence of this will be considerable price cutting.

New machines and new methods are most difficult to select from this great variety of similar units. Many of the machines described in the pages of technical journals were, of course, not new, and in a few cases merely very slight adaptations were presented as innovations.

The Olympia show, which was concentrated in a smaller area and less grouped according to the functions of the machines, appeared to the uninitiated to be much nearer to the workshop floor than some of the giants and new ideas apparently created on the Continent. Undoubtedly, most of the machines we saw at Olympia recently will already be producing goods in customers' workshops, or may have actually spent only a " busman's holiday " at the show. The giant machines were lacking, with the exception of some machines made by Giddings & Lewis, Kendall & Gent, and Richards, which nevertheless, do not approach the dimensions of the Berthiez, Innocenti, Schiess, Waldrich and Froriep machines at Hanover.

Did Hanover or London give more hints for the future ?

The German designers were busy during the war exploiting the (originally American) idea of unit construction machines, envisaging that the future machine may be built up of unit bases, unit spindle heads, unit feed gears, etc. Whilst some standardisation was attempted, a number of manufacturers soon utilised this idea to develop complete machine tools for specialised production, ultimately to be assembled to form transfer machines. Undoubtedly, the greatest success with this system was achieved by the prominent firm of Heller, but at least five other German manufacturers are specialising in these so-called " Fertigungsmaschinen aus Aufbaueinheiten." It is a fundamental and far-reaching idea, which, incidentally, is followed only by a single British manufacturer. It is the totalitarian idea in machine tool design, i.e., the desired success is only achieved when this system is accepted by all, but before this happens, the machine built up of units in so-called " Baukasten " fashion will be so expensive that only specialised industries can afford it.

The popular conception that the Continent invents and Britain takes over is reversed in the case of electromechanical machining. Here we see a new principle in machining where no actual contact takes place between tool and workpiece. These are practically stationary, no high speeds being necessary and no vibrations being caused. Furthermore, the wear of the tool becomes negligible. This seems to be a real challenge to the modern chip-producing machine tool with its high speeds and all its sensitive organs. Will it reduce the future machine tool merely to performing the function of adjustable holders ? It is ironical that the method was shown on a modern radial drilling machine exemplifying the utmost ingenuity in design and construction, the large heavy overhanging arm showing no deflection and responding to a touch of the finger tip.

(*Concluded on page* 364)

RUSSIA

An Analysis of Feed Mechanisms in Machine Tools Regarding Uniformity of Advance and Sensitivity of Adjustment

By M. E. ELYASBERG. (From *Stanki i Instrument*, No. 11, 1951 and No. 12, 1951, pp. 1-7 and 6-9, respectively, 16 illustrations.)

(Concluded from September issue.)

V. COMPARISON OF ANALYSIS AND OBSERVATIONS.

In Fig. 9 curves of displacement x, velocity $\dot{x}$ and friction force y are shown as derived from eqs. (9), (10) and (11), when their parameters are derived from tests such as those recorded in Fig. 4. In this case $v_f = 2{\cdot}5$ mm/sec, $c = 195$ kg/mm, $m = 0{\cdot}0206$ slugs. The area of the surface in contact $s = 98$ cm².

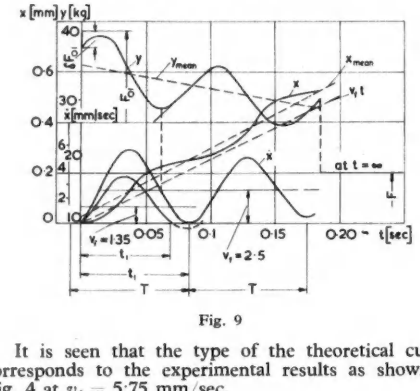

Fig. 9

It is seen that the type of the theoretical curves corresponds to the experimental results as shown in Fig. 4 at $v_f = 5{\cdot}75$ mm/sec.

As seen from eqs. (9), (10) and (11), the curves represent oscillations containing a sinusoidal and an aperiodic term. The line representing v_f is displaced from the average values of $\dot{x}$ owing to the existence of the first term in eq. (11), and this situation corresponds to experimental data discussed under paragraph I, and confirms that the motion is described by equations of the third order. The friction force y is approximately in phase with the acceleration and, as the oscillations attenuate, approaches the magnitude $F_0 + b\,v_f$.

Eq. (15) shows why the frequency ω is below the frequency k of harmonic vibrations. The dependence of y upon the acceleration introduces into the equations the magnitude $m_1 = (1 + \beta_2)\,m$. This magnitude is considerably larger than m since $\beta_2 = b_2/N = 0{\cdot}87$. Hence $k_1 < k$.

The presence of the term y_1 in eq. (4′) causes the multiplier $b_1/(b\,\alpha)$ to be associated with k_1^2 in eq. (15). Since this multiplier is always below unity (in eq. (13) b is negative) there is another reason for the decrease in the frequency ω.

The oscillations are damped if the real part of eq. (12) is negative. It follows from eq. (13) that the absolute value of α exceeds b_1/b and since m_1 exceeds m, it can be concluded from eq. (14) that a minimum value of b_{fr}/m is required to ensure the damping of the oscillations.

In this manner the fall in the friction force with increasing velocity which promotes the amplification of the oscillations is compensated by the internal friction in the material of the transmission.

It must be pointed out that the degree of amplification of the oscillations caused by the fall in the friction force with increasing velocity in no way corresponds to the slope of the characteristics which represent the friction force in established motion (Fig. 8). In reality, the amplifying effect of the fall in friction force is small owing to the slowness of this fall during the transition period (Fig. 6).

Eq. (11) and Fig. 9 can be used to clarify the causes of possible intermittent stops in the motion considered here. The oscillations have a phase angle expressed by $\tan^{-1} C_2/C_3$, provided the phase shift due to damping is neglected. Since the function $\dot{x}$ starts from 0 at $t = 0$, it follows that the minimum of $\dot{x}$ at $t < 0$ is negative. Consequently, if the attenuation of the oscillations of $\dot{x}$ is not fast enough, its first minimum at positive t will also be negative, and the velocity will vanish before reaching the first minimum, i.e., where the curve of $\dot{x}$ intersects the abscissa axis. This is the cause of intermittently arrested motion.

In Fig. 9, at $v_f = 2{\cdot}5$ mm/sec, a critical case is shown in which the curve of $\dot{x}$ only touches the abscissa axis. In the same figure an $\dot{x}$-curve valid for $v_f = 1{\cdot}35$ represents a case of intermittent stops. Thus, with a decrease in the magnitude v_f, more powerful damping is needed to avoid stoppages.

From Figs. 5 and 9 it is seen that the function x fluctuates not about the line $v_f\,t$, but largely above it. This is explained by the gradual decrease in the deformation of the transmission link with the reduction in the friction force. This causes additional displacements as seen before in eq. (6).

For a better understanding of the nature of this motion, it is useful to draw the curve representing the relation between $\xi = x - v_f\,t$ and $\dot{x}$, by excluding the time from the functions $\xi(t)$ and $\dot{\xi}(t)$. This procedure yields the so-called trajectory in the phase plane. This trajectory (Fig. 10), constructed for the case of Fig. 9, has the shape of a spiral which is gradually displaced to the right. In the process of dying out of the oscillations, the phase point approaches position A, which is a point on the abscissa axis at a distance from the origin given by the expression $l_1 = [\delta\,F_{01} - (b + b_{\text{fr}})\,v_f]\,c$.

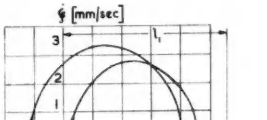

Fig. 10

If the straight line through the origin O_1 of the trajectory and parallel with the abscissa axis is a tangent of the first loop of the spiral, then the motion is a borderline case between continuous and intermittent motions. If the loop is wholly above the line, the motion is continuous, and if the line intersects the loop the motion is intermittent. Variation of the elasticity c does not change the origin O_1 of all trajectories.

VI. DETERMINATION OF CRITICAL FEED VELOCITY.

To ensure continuous motion following the first oscillation, the function $\dot{x}$ must, at the instant t_1 of passing through its first minimum, satisfy the condition:

$$\dot{x} \geqslant 0$$

The integration constants C_1, C_2 and C_3 can be re-written in the following form :

$$\left.\begin{aligned} C_1 &= \varphi_1 v_f + \psi_1 \delta F_{01} \\ C_2 &= \varphi_2 v_f + \psi_2 \delta F_{01} \\ C_3 &= \varphi_3 v_f + \psi_3 \delta F_{01} \end{aligned}\right\} \quad .. \quad .. \quad (16)$$

Introducing C_1, C_2 and C_3 into eq. (11), replacing t by t_1 and equating $\dot{x}_1$ to zero, we find the magnitude of the critical speed to be proportional to δF_{01} :

$$v_f^* = \frac{\delta F_{01}}{\omega^2} \frac{(\omega^2 - k^2)\,\alpha\, e^{\alpha t_1} + [(k^2 - \omega^2)\,\alpha \cos \omega t_1 - k^2\, \omega \sin \omega t_1]\, e^{r t_1}}{\alpha\, b\, e^{\alpha t_1} - \{(b\,\alpha + c) \cos \omega t_1 + [(b\,\alpha + c)\, r/\omega - (b_p/m + 2r)\, c/\omega] \sin \omega t_1\}\, e^{r t_1} + c} \quad (17)$$

It follows that the stoppages are caused by a discontinuity in the friction force between rest and motion. To obtain continuous motion, the effect of the discontinuity must be compensated by damping.

The part played by the discontinuity is confirmed in experiments. Non-metallic materials have almost no discontinuity δF_{01}. Experience shows that these materials, in the presence of lubrication, do not in fact produce intermittent motion. The same observation was made by the author on leather and fibreboard, under non-laboratory conditions.

VII. Practical Application of Theoretical Analysis.

In practical applications the relations previously derived can be considerably simplified without noticeable loss of accuracy.

The normal load N is found from an expression which takes into account the " sticking " force depending upon the size of the surface area

$$N = G + p_{01}\, S \quad .. \quad .. \quad (18)$$

where G = external normal force, and
p_{01} = specific pressure due to sticking at rest.

The static friction is given by the expression :

$$F_{01} = f_{01}\, N = f_{01}\, (G + p_{01}\, S) \quad .. \quad (19)$$

In most cases practical analysis is concerned with the critical speed v_f^* and with the magnitude of the smallest possible displacement x_1 (sensitivity) appropriate to the speed with which the slide or carriage is operated. With hand operation it is permissible to regard the sensitivity x_1 at zero advance as the appropriate value.

In the expressions (13) and (15) the quantities b_p and r^2 can be neglected without much error. We then obtain for α and ω^2 :

$$\alpha \approx \frac{1}{b\,(1/b_1 - 1/c)} \quad .. \quad .. \quad .. \quad (13')$$

$$\omega^2 \approx k_1^2\, b_1/b\,\alpha \quad .. \quad .. \quad .. \quad (15')$$

Having found ω it is easy to compute b_p and then from eq. (14) the magnitude r.

In full-scale design where transmissions of large stiffness occur, eq. (17) for v_f^* can be greatly simplified :

$$v_f^* = \frac{-e^{r t_1} \sin \omega t_1}{\omega\, m\, (1 - e^{r t_1} \cos \omega t_1)}\, \delta F_{01} \quad .. \quad (17')$$

In order to use eq. (17′) it is essential to determine the time interval t_1, which passes from the beginning of the motion until the first minimum of velocity (Fig. 9). It is good enough to neglect the influence of the aperiodic term and of the damping on the period of oscillation.

In eq. (17′) it is convenient to use the expression

$$t_1 = \frac{2\pi - \tan^{-1}(C_2/C_3)}{\omega} \quad .. \quad (20)$$

The integration constants C_2 and C_3 required for eq. (20) themselves depend on the velocity of advance.

For the first approximation an arbitrary or estimated value of v_f^* is introduced into the expressions for C_2 and C_3. Thereupon eqs. (20) and (17′) are used and the resulting value of v_f^* is, in turn, introduced again into the expressions for C_2 and C_3. It is usually sufficient to carry out one cycle and use the second approximation.

The simplified formulae for the integration constants are :

$$\left.\begin{aligned} \frac{C_1}{m} &= \frac{v_f\, b + \delta F_{01}\,(k^2/\omega^2 - 1)}{C} \\ \frac{C_2}{m} &= -\frac{v_f\,(b_p/m + 2r) + \delta F_{01}/m}{\omega^2} \\ \frac{C_3}{m} &= -\frac{v_f\,(b\,\alpha/c + 1)}{\omega} + \frac{\delta F_{01}\,[k^2\,(r - \alpha) + \alpha\,\omega^2]}{c\,\omega^3} \end{aligned}\right\} \quad (21)$$

To compute the smallest possible hand adjustment we introduce into the expressions (21) and (9) the condition $v_f = 0$. We obtain a function little different from a sinusoidal relation with a phase angle around zero. Hence, it is permissible to assume that the time interval t_1, after which the motion will stop (in other words, $\dot{x}$ will vanish), will be approximately equal to one-half of the natural period

$$t_1 \approx \pi/\omega = T/2$$

The minimum adjustment then becomes :

$$x_1 = \frac{\delta F_{01}}{c} \left[\frac{(k^2 - \omega^2)\, e^{\alpha T/2} + k^2\, e^{T/2}}{\omega^2} + 1\right] \quad (22)$$

When the stiffness c is large, the natural period T is small, and it can be assumed that

$$e^{\alpha T/2} \approx e^{rT/2} \approx 1 \text{ and } b_1/b \approx \alpha.$$

It follows that, in view of eq. (15′), we obtain from eq. (22) the following simplified expression :

$$x_1 = 2\,\delta\, \frac{F_{01}}{c}\,(1 + \beta_2) \quad .. \quad .. \quad (22')$$

This simple equation permits a rapid estimate of the stiffness of the transmission needed for a given minimum adjustment x_1.

In very heavy machines it may be profitable, in order to avoid excessive weight of the transmission, to allow intermittent motion to take place. However, the " jumps " of the tool carriage which take place in such motion must be sufficiently small. From eq. (9) we conclude that the " jumps " grow with the increase in feed velocity v_f. Therefore, in order to obtain the largest " jump " x_{max} which may occur, we have to introduce the time interval t_1 from eq. (20) into the eq. (9).

In this procedure the integration constants are determined from eq. (21) after substitution of v_f^* for v_f.

To find the " jump " x_v at any speed of advance, it is necessary to introduce the time interval t_{1v} into eq. (9). Before doing so, we have to find t_{1v} from eq. (11), introducing the condition that $\dot{x}$ vanishes. The first approximation to t_{1v} may be derived on the assumption $e^{\alpha t_{1v}} = e^{r t_{1v}} = 1$.

Then t_{1v} is found from the remaining simple trigonometrical equation. From the t_{1v} value obtained, $e^{\alpha t_{1v}}$ and $e^{r t_{1v}}$ are again computed and introduced into

eq. (11) in order to obtain the subsequent approximation and so on.

To ensure good surface quality and appearance of the machined component it is essential that the magnitude of the "jump" x_v should be small compared with the typical feed advance per spindle revolution for fine machining. For example, at an advance of 0·1 mm/rev., a "jump" of 0·02 mm will have a negligible effect on appearance and quality of the machined component.

Evidently, the cycle of a discontinuous oscillation is composed of the duration of a "jump" and the time needed for storing the energy of deformation after the jump.

$$T_v = t_{1v} + \frac{x_v - v_f t_{1v}}{v_f} = \frac{x_v}{v_f} \quad .. \quad .. \quad (23)$$

In the analysis of the transmission of a feed mechanism with an automatic control of advance, such as in electrical or hydraulic transmissions with a wide range of feeds, or in a follow-up transmission, it is necessary to regard the frequency $f_v = 1/T_v$ as an exciting frequency.

Expressions (13), (14) and (15) show that the only means for the reduction of critical speed and the increase of the "sensitivity" of the feed transmission at a given friction force and moving mass, is an increase in the stiffness of the transmission.

The stiffness c of the transmission, referred to the point of application of the friction force y, in other words, to the output pair of links of the transmission mechanism, is in fact dependent upon the stiffness of all the elements of the transmission.

The internal damping in the material of the transmission, which, as shown in Sections II and V, plays an important part in the dying-out of oscillations, was assumed to be dependent upon the nature of the loaded state.

An evaluation of internal friction requires a summation over the whole transmission.

The summation is that of terms which are products of the stiffness of separate components, and the squares of the corresponding amplitudes.

VIII. Values of Constants.

The friction between two components of cast iron lubricated with machine oil, at a specific pressure of about 2 kg/cm² and at room temperature, is expressed by the recommended value of β between — 0·022 and — 0·036 sec/mm. For calculations to establish the continuity of motion a larger value of β should be taken to ensure a margin of safety, but the lower limit can be recommended for laboratory analysis and for estimates of efficiency. Other magnitudes have the following values :

$\beta_1 = 0{\cdot}09$ mm^{-1} $\quad \beta_1/\beta_2 = b_1/b = -2{\cdot}53$ sec^{-1}
$\beta_2 = 87$ $\quad \delta = 0{\cdot}06$ to $0{\cdot}09$.

The lower limit of δ is recommended for calculations to establish continuous motion in accordance with eq. (17′). The upper limit of δ should be used for estimating the sensitivity to adjustments after prolonged standstill in accordance with the eqs. (22) and (22′), as well as for the determination of the length of jumps.

The constants of internal dissipation applicable to steel under flexure, extension and compression, are $\beta_p = 0{\cdot}07$; under torsion $\beta_p = 0{\cdot}05$.

The coefficient of static friction is $f_{01} = 0{\cdot}18$ provided the "sticking" effect is separately accounted for. The specific pressure due to "sticking" at rest is $p_{01} = 0{\cdot}22$ to $0{\cdot}25$ kg/cm². This value corresponds to a specific "sticking" force of 0·040 to 0·045 kg/cm².

IX. Sequence of Analysis.

To carry out the analysis, the following magnitudes must be given : mass m, normal pressure G (if different from weight), friction surface area S, lowest speed of feed v_f and permissible sensitivity of adjustment x_1.

If the analysis is carried out for the purpose of ensuring the desired conditions in finish machining, then the cutting forces on the edge of the tool can be neglected; the cutting edge forces in line with the friction force can equally be neglected since they have a damping effect. If the moving part of the machine has balancing weights, their mass should be deducted from the total mass m (without reducing the weight G). The following steps can be recommended in analysis :

(1) The normal force N is found from eq. (18) and the friction force F_{01} at rest from eq. (19).

(2) The constants b, b_1, b_2 and the discontinuity in the friction force δF_{01} are computed (see section II).

(3) From the given sensitivity of adjustment x_1 we find a preliminary effective stiffness c using eq. (22′) and calculate the corresponding stiffness of the actual transmission.

(4) We find the quantity α from eq. (13) and then the frequency ω from eq. (15′).

(5) We compute the effective value of β_{pn} (taking into account only those links of the transmission which make a significant contribution).

(6) We calculate the magnitude r from eq. (14).

(7) We find the minimum possible displacement x_1 from eq. (22). If x_1 is large, it is necessary to increase the stiffness. The relation $x_1 \leqslant (0{\cdot}1$ to $0{\cdot}2)\ \Delta$ can be recommended for guidance, where Δ is the magnitude of the smallest adjustment which must be ensured in machining. Normally the value $x_1 \leqslant 0{\cdot}005$ to $0{\cdot}02$ is acceptable, sometimes rising to 0·05 mm in heavy machines.

(8) We obtain the values C_2/m and C_3/m from eqs. (21) using the value of the minimum speed of feed v_f, and then find ωt_1 and t_1 from eq. (20).

(9) We verify the magnitude of the critical speed v_f^* from expression (17′). If the value v_f^* is satisfactory, then the calculation is completed. Otherwise, it is necessary to increase the stiffness or to tolerate intermittent movement at speeds of feed below v_f^*.

(10) If intermittent motion can be tolerated, then the maximum value of the jump x_{max} must be checked, having first found the deficiency in the quantity C_1/m from eq. (21).

(11) When the machine contains a mechanical transmission for fine tool adjustments, its sensitivity of displacement can be evaluated by introducing t_{1v} into eq. (9). This new equation is inaccurate and conservative, because the influence of the transient processes in starting and stopping of the transmission is not taken into account. To avoid complicating the calculations, it is possible to use a quantity between x_1 from eq. (22) and $x_v = x\,(t_{1v})$ as it can be found from eq. (9).

CONCLUSIONS.

It follows from eq. (17) that the required stiffness of the transmission and the critical speed can be reduced when the friction force at rest F_{01} is decreased, because this simultaneously reduces the drop δF_{01}. This conclusion leads to the design of special slides with spring-supported sliding surfaces. In such designs it is possible to replace sliding friction largely by rolling friction. Such designs have been successfully introduced by the author in lathes constructed by the Sverdlov factory.

The application of materials different from cast iron for the mating surface also allows a reduction in the drop of friction force, and hence leads to a reduction of the critical velocity. In particular, a large effect is attained by means of amorphous materials, such as plastic materials, some of which can almost eliminate the drop in friction force, and therefore the intermittent motion. It must be remembered, however, that the absolute value of the friction force remains large.

Properties of some High Titania Dielectric Ceramics

By E. G. Graf. (From *Ceramic Bulletin*, Vol. 31, No. 8, August 1952, pp. 279-282, 8 illustrations.)

The properties of the more common titanates and the steps necessary to fabricate dielectric bodies are briefly discussed. Various methods of altering the dielectric properties over the normal temperature range by means of additions which affect the crystal structure are illustrated for capacitors consisting mainly of barium titanate.

The widespread use of ceramic materials as dielectrics in capacitors as differentiated from their use as insulators is fairly recent. Today most condensers used in electronic equipment such as television and radio receivers are ceramic types. This rapid acceptance of ceramic capacitors was occasioned by the short supply of dielectric material during World War II. Since the war, there has been a demand for miniature electronic and communication equipment and the high dielectric constants of the titanates make them ideally suited to meet this requirement. Consequently, bulky capacitors have been replaced in many instances by the much smaller titanate ceramic capacitors.

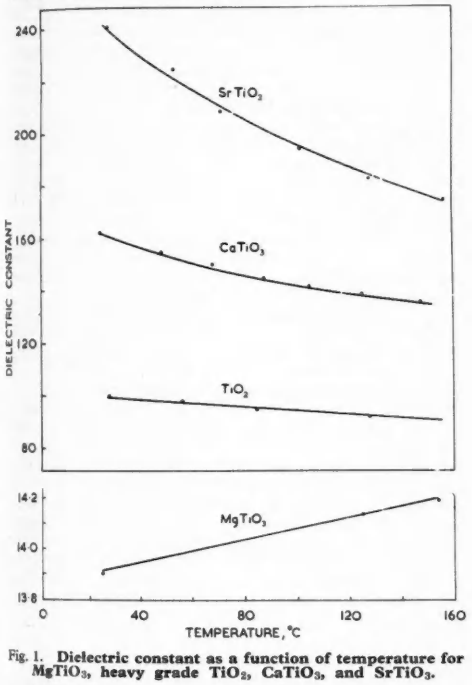

Fig. 1. **Dielectric constant as a function of temperature for $MgTiO_3$, heavy grade TiO_2, $CaTiO_3$, and $SrTiO_3$.**

Figure 1 shows how the dielectric constants, as measured at 1 mc of four of these titanate dielectrics vary with temperature. Magnesium titanate with a dielectric constant of about 14 and 0·025 per cent power factor at 1 mc, has a positive temperature coefficient of 150 ppm per °C. The next highest dielectric constant shown is that of titanium dioxide with a power factor of about 0·05 per cent. Its temperature coefficient has a negative value of about 750 ppm per °C. Calcium titanate follows with a dielectric constant of 153, 0·03 per cent power factor and a negative temperature coefficient of 1800 ppms per °C. The highest dielectric constant of this group is that of strontium titanate, the value being about 240 at 25° C, with a power factor of 0·012 per cent. These four dielectrics with their wide range of dielectric constants and temperature characteristics, and low power factors, make up a very desirable group to replace other types of dielectric material.

Despite the valuable properties and the widespread usage of these materials, it is another titanate, the properties of which at first glance seem somewhat unattractive, around which the greatest amount of interest gravitates. This is barium titanate; its electrical properties are illustrated in Fig. 2 as a function of temperature.

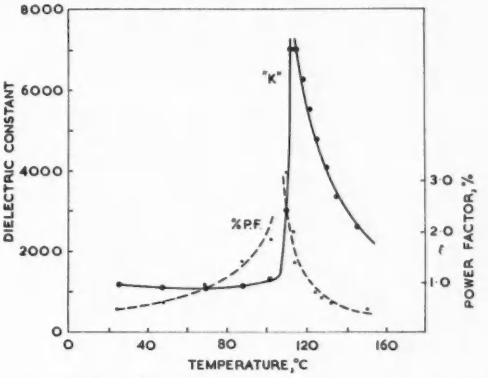

Fig. 2. **Dielectric constant and per cent power factor of $BaTiO_3$ as a function of temperature.**

In recent years, more research effort has been devoted to the properties of barium titanate than to perhaps any other dielectric material. This is due not only to the fact that it has the highest individual dielectric constant of all the titanates but also because it is ferroelectric and piezoelectric. Its application to capacitors stems from the discovery that its properties could be altered in many ways by the addition of other materials.

Titanates are produced by high-temperature reactions with subsequent milling of the calcined material to pass a 325-mesh screen. While the method of fabrication of these powders into a satisfactory electrical body is similar to that used in other ceramic fields, there is the essential difference that the finished product must have satisfactory electrical as well as ceramic properties.

The final form for the capacitor may be obtained by such procedures as slip casting, extrusion, or pressing. The method which Titanium Alloy Manufacturing Division uses for control testing may be outlined as follows:

(1) The powder is tempered with 8 per cent water, thoroughly mixed and screened twice through a 20-mesh screen.

(2) Five 1-in. diameter disks are prepared from the above powder at a forming pressure of 10,000 psi, the time of holding pressure being approximately 5 seconds.

(3) The formed disks are then placed in saggers which have been previously dusted with zirconium oxide powder, which has been found to be the most satisfactory setter material for firing the titanate dielectric bodies. No interaction between ZrO_2 and the dielectric body results as is the case with other materials such as silica, alumina, and zircon. One method of using ZrO_2 is as a fine powder dusted on a setter plate or sagger which may be a zircon or high-fired clay body. Stabilized zirconia plates or saggers can also be used without dusting. The settered disks are then placed in the furnace at room temperature and heated to peak temperature in 3½ to 4 hours. In the case of $SrTiO_3$, $CaTiO_3$, and $MgTiO_3$,

the peak temperature is 2400° F while for $BaTiO_3$ and heavy grade TiO_2 the peak temperature is 2450° F. After two hours at the peak temperature, the disks are furnace cooled overnight.

(4) The disks are measured to determine the diametric firing shrinkage.

(5) The faces of three of the disks are silvered and fired to 1500° F for ½ hour and cooled overnight with the furnace. Heating to 1500° F from room temperature requires 2 to 2½ hours.

(6) On cooling, the silvered disks are tested for dielectric capacity and power factor at a frequency of 1 mc.

(7) The remaining fired disks, two in number, which were not silvered, are weighed, immersed for 2 hours in boiling distilled water, wiped dry, and reweighed to determine the per cent water absorption.

While this procedure lists the steps to be followed, it does not sufficiently emphasize the care and attention that must be paid to details which in other ceramic processes might be insignificant.

The properties plotted in Fig. 2 were determined from barium titanate prepared by following the listed procedure. It will be noticed that although the room temperature dielectric constant of approximately 1300 is considerably above that of other dielectric materials, the peak value of about 8000 is reached only at approximately 118° C. A considerable amount of effort has been devoted to altering these temperature-dielectric-constant relations in order to change the temperature at which the peak value of dielectric constant is obtained and/or to broaden the temperature range over which high values are found.

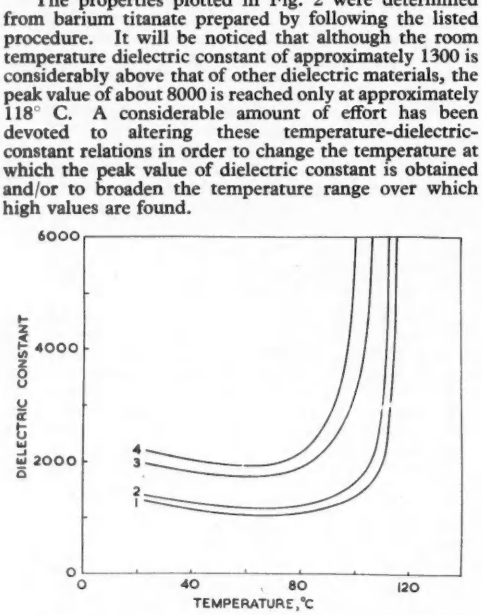

Fig. 3. **Dielectric constant vs. temperature characteristics of $BaTiO_3$, as affected by varying the $BaO:TiO_2$ ratio. Composition of Curve (1) 1 BaO, 1·04 TiO_2; Curve (2) 1 BaO, 1·02 TiO_2; Curve (3) 1 BaO, 0·98 TiO_2; Curve (4) 1 BaO, 0·96 TiO_2.**

To understand the effects of the various additions, it should be remembered that the usual dielectric properties of barium titanate are due to the spatial relationship of the atomic units making up its crystal lattice. Barium titanate is tetragonal below 118° C and at about that temperature it transforms to a perovskite type structure. It is at this transformation or Curie temperature that the spatial relationship is such that the highest values of dielectric constant are reached. In order to shift the Curie temperature, the crystal lattice must be altered. Perhaps the most direct method of accomplishing this would be to alter the ratio of barium oxide to titanium dioxide slightly from the one to one mole ratio. Figure 3 shows the effect upon the temperature-dielectric constant characteristics as this ratio is varied. It is seen that as the barium oxide is increased from a deficiency to an excess, the dielectric

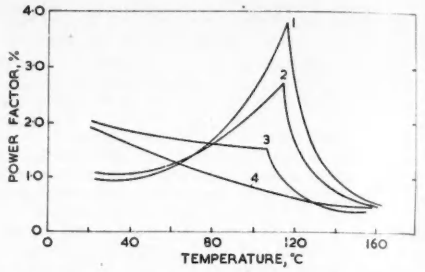

Fig. 4. **Per cent power factor vs. temperature characteristics of $BaTiO_3$ as affected by varying the $BaO:TiO_2$ ratio. Composition of Curve (1) 1 BaO, 1·04 TiO_2; Curve (2) 1 BaO, 1·02 TiO_2; Curve (3) 1 BaO, 0·98 TiO_2; Curve (4) 1 BaO, 0·96 TiO_2.**

constant increases and the Curie temperature decreases. The general shape of the dielectric-constant curve has not been altered, but Fig. 4, which illustrates the temperature characteristics of the power factor of the same bodies, shows that the power-factor curve undergoes profound changes. The increase in power factor of the high barium oxide bodies at working temperatures is one reason for avoiding their use.

While it has been shown that a deficiency of BaO will slightly increase the Curie temperature, a more drastic increase can be caused by the addition of lead titanate which raises the Curie temperature by almost 20° C and thus increases the temperature range over which no drastic shifts in capacity occur. While lead titanate is one of the few additions which increase the Curie point, a wide choice of additions (such as the stannates of calcium, strontium, and barium) is available for shifting this temperature lower.

The examples so far given have comprised additions which simply shifted the temperature at which the peak value of dielectric constant occurs; for example, the 10 per cent calcium stannate body has an extremely high dielectric constant at room temperature, but if it were used in compact electronic equipment operating at higher temperatures, its performance would be very different. For such service, an agent is needed that will broaden the sharp peak characteristic of the Curie point. Such an effect is illustrated by Fig. 5, which shows the dielectric properties of a blend of 95 per cent by weight of $BaTiO_3$ and 5 per cent of $MgO{\cdot}ZrO_2$ at various temperatures. For applications such as by-pass, filter, or coupling capacitors where only moderate temperature stability is required, such a blend offers a material of moderately high dielectric constant, useful over a wide range of temperatures.

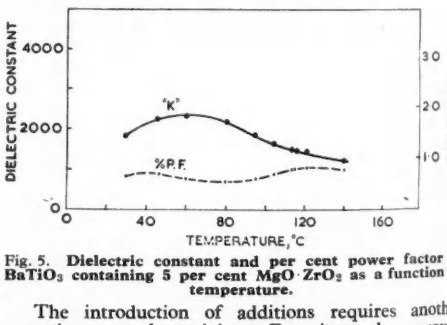

Fig. 5. **Dielectric constant and per cent power factor of $BaTiO_3$ containing 5 per cent $MgO{\cdot}ZrO_2$ as a function of temperature.**

The introduction of additions requires another operation, namely, mixing. Experience has proved that wet milling produces more consistent electrical results than dry blending. Since the purpose of the wet milling is to produce a uniform blend rather than

(*Concluded on page* 364)

Design and Arrangement of Cooling Fins

By F. HEILES. (From *Elektrotechnik und Maschinenbau*, Vol. 69, No. 14, July 15, 1952, pp. 323-331, 10 illustrations.)

Completely enclosed electrical machines provided with surface cooling are becoming increasingly important for many applications. To maintain their overall dimensions within reasonable economic limits for a given power rating, it is necessary to increase the area of the surfaces in contact with the cooling air by means of fins arranged along the axial direction of the casing. The object of this article is to determine the most favourable design arrangements of the cooling fins.

MOTOR casings are either castings or welded rolled-steel constructions. The fins are cast integral with the casing in the former, and welded-on in the latter case. Both types of fins are of approximately rectangular cross-section and can be represented as shown in Fig. 1.

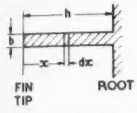

Fig. 1. **Fin element, showing symbols used.**

The fin with a length L in the axial direction can be regarded as consisting of elements of a length ΔL, each element having a height h and a width b. The tip of the fin will be denoted by $x = 0$, and the root by $x = h$. Owing to the difference in temperature, there is a flow of heat into the fin from the casing in the $-x$ direction. The temperature θ and the heat flow per second q through a section dx of the element increase with positive values of x. The cooling air generally flows along the side surfaces of the fin without touching the free-end surface of the fin tip, which can therefore be disregarded. However, it can be taken into account if necessary by increasing the height of the fin to a value $h + (b/2)$.

At $x = 0$, the heat flow is $q(0) = 0$, and at $x = h$, we have $q(h) = q_h$, these being the boundary conditions. Let

λ = thermal conductivity of fin material,

a = heat transfer coefficient of surface,

$\theta = \theta(x)$ = temperature difference between cooling air and fin surface at any position x,

then the heat and temperature conditions in a fin element dx are given by the equations

$$dq = A\,\theta\,dx \quad \text{and} \quad d\theta = Rq\,dx \qquad .. \qquad (1)$$

where $A = 2\,a\,\Delta L$ and $R = 1/(\lambda\,b\,\Delta L)$. Therefore,

$$dq/dx = A\,\theta \quad \text{and} \quad d\theta/dx = Rq \qquad .. \qquad (1')$$

and hence

$$d^2q/dx^2 = A\,d\theta/dx = ARq \qquad .. \qquad (2a)$$

$$d^2\theta/dx^2 = R\,dq/dx = AR\,\theta \qquad .. \qquad (2b)$$

By using the substitution $q = K\,e^{\psi x}$, and the abbreviation $\alpha^2 = AR$, in conjunction with eq. (2a), we obtain

$$\psi = \pm\sqrt{AR} = \pm\,\alpha$$

so that the general solution is

$$q = K_1\,e^{\alpha x} + K_2\,e^{-\alpha x} \qquad .. \qquad .. \qquad (3)$$

Since $q(0) = 0$, and hence $K_2 = -K_1$, eq. (3) becomes

$$q = K_0 \sinh \alpha\,x \qquad .. \qquad .. \qquad (3')$$

Moreover, as $q(h) = q_{max} = q_h$, we may write

$$q(x)/q_h = \sinh \alpha\,x/\sinh \alpha\,h \qquad .. \qquad .. \qquad (4)$$

The temperature distribution, from eqs. (1') and (3'), is determined as

$$A\,\theta = \alpha\,K_0 \cosh \alpha\,x$$

and as $\alpha^2 = \psi^2 = AR$ and $K_0 = q_h/\sinh \alpha\,h$, this gives finally

$$\theta(x)/\theta_h = \cosh \alpha\,x/\cosh \alpha\,h \qquad .. \qquad (5)$$

Furthermore, the heat-flow/temperature ratio at the root of the fin is

$$\Lambda = q_h/\theta_h = \sqrt{(A/R)}\,\tanh \alpha\,h \qquad .. \qquad (6)$$

Eqs. (4), (5) and (6) give all the relations required. For instance, if the temperature difference θ_h between the fin surface at the root position and the cooling air is assumed to be known, eq. (5) gives the excess temperature θ at any point x. The value of q_h is obtained from eq. (6) and the heat flow q at x is determined by means of eq. (4).

The value of the thermal conductivity λ for cast-iron fins is, on average, approximately $\lambda = 0{\cdot}50$ watt/(°C cm). The surface heat transfer coefficient $a = 20$ — 200 watt/(°C m²), the lower value being for air flow velocities usually occurring in practice and the higher value for velocities associated with considerable turbulence. To fix the ideas, it will be useful to consider a fin cross-section with the dimensions $h = 5$ cm and $b = 0{\cdot}5$ cm. For this instance, the table below gives the values of θ/θ_h and q/q_h as functions of x for three different values of a.

	$a = 20$		$a = 100$		$a = 200$	
x	θ/θ_h	q/q_h	θ/θ_h	q/q_h	θ/θ_h	q/q_h
0	0·82	0·0	0·45	0·0	0·26	0·0
1	0·83	0·19	0·47	0·15	0·29	0·12
2	0·85	0·38	0·53	0·30	0·38	0·24
3	0·88	0·58	0·63	0·50	0·48	0·31
4	0·94	0·78	0·79	0·72	0·69	0·65
5	1·0	1·0	1·0	1·0	1·0	1·0

The heat-flow/temperature ratio Λ at the root of the fin is of considerable importance. High values of Λ are required in order to obtain efficient cooling, i.e., good heat-transfer conditions. Using the abbreviations

$$m^2 = 2a\,(\Delta L)^2\,\lambda \quad \text{and} \quad n^2 = 2a/\lambda$$

in conjunction with the expressions for A and R, we may re-write eq. (6) as follows :—

$$q_h/\theta_h = \Lambda = m\sqrt{b}\,\tanh\left\{\,nh/\sqrt{b}\,\right\} \qquad .. \qquad (6')$$

This result shows that the heat flow per degree of temperature difference does not depend only on the ratio h/b. This is true even when values are related to unit volume. For small values of $nh/\sqrt{b}$, the hyperbolic tangent may be replaced by its argument. Then $\Lambda = m\,n\,h = 2\,a\,h\,\Delta L$, that is, independent of b. As, however, the volume increases with b, favourable values are obtained when b is kept as small as possible. When $nh/\sqrt{b}$ is large, the hyperbolic tangent is approximately equal to unity, so that $\Lambda = m\sqrt{b}$, that is, it increases proportionally to $\sqrt{b}$. Again, as the volume increases with b, in this case also it will be advisable to use small values for b.

Numerical values for the heat-flow/temperature ratio Λ as a function of fin thickness b are given in the following table, for the example already considered ($h = 5$ cm, b = variable).

The values of Λ/b, which relate Λ to unit volume or unit weight, are also included in this table, and clearly show the advantages of using small fin thicknesses b. The fin cannot be made extremely thin without impairing its mechanical strength and raising manufacturing problems. The lower limit is at about

b cm	a = 20		a = 100		a = 200	
	Λ	Λ/b	Λ	Λ/b	Λ	Λ/b
0	0·0	—	0·0	—	0·0	—
0·1	0·013	0·130	0·030	0·300	0·044	0·440
0·2	0·015	0·075	0·045	0·225	0·066	0·330
1·0	0·186	0·186	0·076	0·076	0·127	0·127
1·4	0·019	0·144	0·082	0·058	0·139	0·100

0·5 cm, which gives good Λ-values, according to the above table, so that b = 0·5 cm will be used as a fixed value in the following considerations.

It is of interest to consider the effect of varying the height h of the fin for a constant b-value. When $h \to 0$, we have

$$\lim_{h \to 0} \Lambda/h = \lim \left\{ (m\sqrt{b}/h) \tanh (n\,h/\sqrt{b}) \right\}$$
$$= (\Lambda/h)_{max} = m\,n = 2a\,\Delta L \quad .. \quad (7)$$

This same limiting value would be reached for $h > 0$ if the fin material had an extremely high thermal conductivity ($\lambda \to \infty$). In this case the entire fin surface would be equivalent as regards heat dissipation to an equally large area of the motor casing. We now define the "fin factor" β :—

$$\beta = \Lambda/\Lambda_{max} = (\sqrt{b}/n\,h) \tanh (n\,h/\sqrt{b})$$
$$= (1/p) \tanh p \quad .. \quad .. \quad (8)$$

using eqs. (6′) and (7), with $p = n\,h/\sqrt{b} = h\sqrt{2a/\lambda\,b}$. The value of β multiplied by the fin surface area gives a reduced area which we can regard as being equivalent to an equal additional area on the casing as regards heat dissipation. The resultant increased area of the casing can then be related to one and the same value of the heat transfer coefficient a.

The following table gives values of β as functions of p and h for a cast-iron fin (the values for different h's are for a fixed b = 0·5 cm and λ = 0·5 watt/cm °C).

p =	0	0·4	0·8	1·2	1·6	2·0	2·4	2·8	3·2
β =	1·0	0·95	0·83	0·70	0·58	0·48	0·42	0·36	0·32

	h =	0	2	4	6	8 cm
a = 20 :	β =	1·0	0·98	0·925	0·84	0·76
a = 100 :	β =	1·0	0·905	0·72	0·55	0·44
a = 200 :	β =	1·0	0·83	0·575	0·415	0·32

In order that the heat dissipation may be as high as possible, it is naturally not sufficient to make β reach high values. An increase in β will have a favourable effect only if the heat-dissipating area is not simultaneously reduced. It is, therefore, necessary to determine how variations in fin thickness and height will affect the size of the surface area.

Assuming that the number of fins remains unchanged, a decrease in fin thickness may give a very small increase in effective surface area, but this is generally counterbalanced by a correspondingly small decrease in the heat-flow/temperature coefficient Λ. Thus, the variation of b has little effect in this respect. However, the fin thickness does affect the amount of material used, and this latter consideration shows that it is an advantage to make the fins as thin as possible.

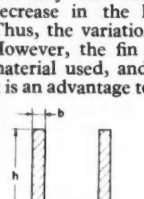

Fig. 2. **Symbols used for determining a fin arrangement.**

The effect of the fin height h is, however, most appreciable. If the height of the fins is reduced, it is necessary to increase the number of fins in order to obtain the same effective cooling area, and this will be examined in greater detail later on.

These remarks show that the complete fin arrangement (see Fig. 2) should be considered in studying the cooling conditions. We shall consider two arrangements of cooling fins, viz. :—

(1) : b_1 = 0·5 cm h_1 = 6·0 cm d_1 = 4·5 cm ;
(2) : b_2 = 0·5 cm h_2 = 3·0 cm d_2 = 2·0 cm.

Both arrangements require the same amount of material and have the same value for side surface area. However, the area of casing surface in contact with the cooling air in arrangement (2) is 8/9ths of that of arrangement (1).

The "effectiveness ratio" γ_a (taking account of the heat transfer coefficient) will now be used as a basis for comparing arrangements (1) and (2). This ratio shall be defined as the ratio of the quantities of heat dissipated per unit area of the casing surface. It is apparent from

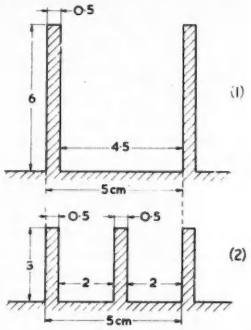

Fig. 3. **Comparison of two different fin arrangements (1) and (2).**

Fig. 3, which refers to arrangements (1) and (2), that

$$\gamma_a = \frac{2\,d_2 + 4\,h_2\,\beta_2}{d_1 + 2\,h_1\,\beta_1} = \frac{(2 \times 2) + (4 \times 3) \times \beta_2}{4{\cdot}5 + (2 \times 6) \times \beta_1}$$

The results are summarised in the following table :—

a =	20	60	100	140	180	200 (watt/m² °C)
γ_a =	1·06	1·17	1·24	1·28	1·30	1·315

Similar comparisons can be made of any other fin arrangements. As long as the same heat transfer coefficient "a" is used in the comparison, it will always be found more efficient to use a larger number of fins of smaller height instead of a smaller number of fins of greater height.

How far this can be carried on depends first on the manufacturing process. Welded ribs cannot be placed extremely close together without trouble in the production of the welding seams. The d/h (spacing/fin height) ratio cannot be less than a certain minimum value. The requirement for closely spaced fins of small height could thus be fulfilled to a considerable extent. However, the manufacturing costs increase in welded casings with increasing numbers of fins, but this factor may be less important than the requirement of maintaining the surface-cooled motor casing within a small size for the range of powers considered. With castings there is no problem in this regard. Nevertheless, each case has to be considered individually.

The use of a large number of fins of reduced height has another important advantage. For the arrangements (1) and (2) already considered, the total flow cross-sections F_1 and F_2 available for the cooling air are considerably different. As arrangement (2) involves twice as many ribs as arrangement (1), the ratio is

$$F_1/F_2 = d_1\,h_1/(2\,d_2\,h_2) = 27\ \text{cm}^2/12\ \text{cm}^2$$

This shows that more than twice as much cooling air is required for (1) than for (2). This involves the use of

a larger cooling fan and as in surface-cooled machines the fan losses are a high proportion of the total losses, the deterioration in efficiency of the machine is considerable. On the other hand, if the same fan power is considered for both cases, the flow velocity for arrangement (2) will be 26 per cent higher than for arrangement (1) and this will appreciably increase the heat transfer coefficient.

In the above, the value of the heat transfer coefficient a was implicitly assumed to be known. In fact, it depends on the air flow velocity, the relative dimensions of the fin system and other variables. For very long fins, the temperature difference θ_h at the root does not have the same value for all root positions along the fin length. To deal with this problem, it is convenient to introduce the value θ_a, as suggested by Richter. θ_a is the value equal to θ_h at the root position at which the cooling air is supplied to the fin system. Furthermore, it is necessary to introduce the following quantities :—

v = flow velocity of cooling air [cm/sec],
k = thermal conductivity of cooling air [watt/cm °C],
s = density of cooling air [gr/cm³],
c = specific heat of cooling air (at constant pressure) [watt sec/gr °C], and
L = axial length of cooling fins [cm].

The flow of air between the fins can be regarded as analogous to the flow of air in channels. Richter published an extensive treatise on this subject, on the basis of Nusselt's results. According to Richter, we may write

$$a = (s\,c\,\delta\,v/4\,L)\,(1 - e^{-m}) \quad \text{watt/cm}^2\,^\circ\text{C} \quad .. \quad (9)$$

where $$m = 0{\cdot}1448\,\frac{L^{0{\cdot}946}}{\delta^{1{\cdot}16}}\left(\frac{k}{s\,c\,v}\right)^{0{\cdot}214}$$

The flow diameter δ [cm] is equal to the internal diameter for channels of circular cross-section. For other shapes it can be determined as

$$\delta = 4\,F/P \quad .. \quad .. \quad .. \quad (10)$$

where F = cross-sectional area and P = perimeter of cross-section. Neglecting the curvature of the machine surface, for a fin arrangement such as that shown in Fig. 2, we have

$$\delta = 2\,h\,d/(h + d) \quad .. \quad .. \quad (10')$$

In applying eq. (10), it should be noted that the perimeter P must also include the " open " side of the channel situated between two fins.

The evaluation of eq. (9) is very laborious, if temperature effects on the constants of the cooling air are also taken into account. For simplicity, we shall assign to s, c and k the values corresponding to a temperature of 40° C, viz. :— $s = 0{\cdot}001128$ gr/cm³ ; $c = 1{\cdot}009$ watt sec/gr °C ; $k = 0{\cdot}000263$ watt/cm °C. With these values, eq. (9) may be rewritten as

$$a = 284{\cdot}55\,(\delta\,v/L)\,(1 - e^{-m}) \times 10^{-6} \text{ watt/cm}^2\,^\circ\text{C} \quad (9')$$

with $$m = 0{\cdot}106\,L^{0{\cdot}946}/[\delta^{1{\cdot}16}\,v^{0{\cdot}214}].$$

It is not easy to see from these expressions the trend followed by the heat transfer coefficient a as a function of the individual variables. The method proposed is, therefore, to try to find whether, in the range of values occurring in practice, there exists for any assumed pair of L- and v-values, an optimum value of δ for which a is a maximum.

The results of a general evaluation are given in the following table.*

The table shows that for short machines (small L-values), the corresponding small values of δ_{opt} are only slightly dependent on the air flow velocity v, whereas for greater machine lengths and larger δ_{opt} values this effect is more pronounced.

TABLE of values of the heat transfer coefficient a [watt/m² °C] as a function of the flow diameter δ [cm], the fin length L [cm], and the air flow velocity v [m/sec]. Valid for smooth channel walls and non-turbulent flow.

L	v	δ			L	v	δ			L	v	δ			
		1	3	6			1	3	6			1	3	6	8
10	5	31	29	26	70	5	16	22	22	130	5	10	18	19	19
	15	76	68	62		15	43	53	52		15	29	46	48	47
	25	115	102	93		25	68	81	79		25	47	70	72	71
	35	149	133	121		35	92	107	103		35	65	93	95	93
	50	199	177	160		50	125	143	137		50	92	125	127	124
30	5	24	25	24	90	5	14	20	21	150	5	9	17	19	19
	15	61	61	57		15	38	50	51		15	26	43	46	46
	25	93	93	86		25	60	77	76		25	43	67	71	70
	35	123	121	112		35	81	102	100		35	58	89	93	91
	50	165	161	148		50	111	136	134		50	82	120	124	122
50	5	19	23	23	110	5	12	19	20						
	15	51	57	54		15	33	48	49						
	25	79	86	82		25	53	73	75						
	35	105	113	107		35	72	97	97						
	50	142	150	142		50	99	130	130						

The tabulated values obtained from eq. (9′) are valid for smooth surfaces and non-turbulent flow. Sudden changes in channel diameter or in the direction of air flow produce turbulences which raise considerably the value of the heat transfer coefficient a. According to the experimental investigations made by Rietschel, this rise is independent of the flow velocity, and can therefore be taken into account by multiplying the results by a " turbulence factor " ξ. His tests and those of Schütte showed values of ξ between 1·7 and 1·9, and it is therefore recommended to multiply the a-values based on eq. (9′) by this factor 1·7-1·9 in cases of turbulent flow conditions, unless further measurements for the special case considered give another value.

Richter's derivation of eq. (9) for cooling processes in channels is based on the assumption that the temperature of the channel walls is the same on all sides. This is not the case with fin systems, but by using the coefficient β we can comply with Richter's requirement, since the true fin surface area is reduced to an equivalent casing area which has the same temperature as the casing.

In the comparison of two fin arrangements it was previously assumed that both arrangements had the same heat transfer coefficient. The a-value did not appear explicitly in the expression for γ_a but was contained in β_1 and β_2. We have now shown that for a given length L and air flow velocity v the a-value is not the same for the two arrangements. Therefore, the corrected " effectiveness ratio " γ_v which should be used is

$$\gamma_v = \frac{[2\,d_2 + 4\,h_2\,\beta_2]\,a_2}{[d_1 + 2\,h_1\,\beta_1]\,a_1} = \frac{[(2 \times 2) + (4 \times 3)\,\beta_2]\,a_2}{[4{\cdot}5 + 2 \times 6)\,\beta_1]\,a_1}$$

Before determining a_1 and a_2, the flow diameters δ_1 and δ_2 have to be obtained from eq. (10′). This gives $\delta_1 = 5{\cdot}15$ and $\delta_2 = 2{\cdot}4$ cm. Then a_1 and a_2 can be obtained from the table for given values of L and v, by means of interpolations if necessary.

When δ_2 is close to δ_{opt} (small lengths L), the superiority of arrangement (2) relative to arrangement (1) is even more marked, since in this case $\gamma_v > \gamma_a$. Only when δ_1 is close to δ_{opt} (and hence $\gamma_v < 1$) is (1) more favourable than (2), if we disregard the advantage of a smaller air quantity for arrangement (2). The above table is therefore a useful means for calculating the heat dissipation of a fin system of given dimensions, without going into the tedious computation of the a-value from eq. (9) or (9′).

In a machine with cooling fins there are generally three types of surfaces to be considered :—

* A more detailed table is given in the original article.
—Editor, E.D.

S_1 = the casing surface which is directly in contact with the cooling air [m²] ;
S_2 = the surface of the fins ; and
S_3 = the surface not in contact with the cooling air.

In general, a heat-transfer coefficient $a' = 14$ watt/m² °C can be assigned to the surface S_3. The total heat dissipation per unit time (in watts) is then obtained as

$$Q = \theta_a [(S_1 + \beta S_2) \xi a + S_3 a'] \quad .. \quad (11)$$

It should be noted that the value of β should not be determined on the basis of a, but of ξa, and it can be calculated or taken from the table previously given.

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BELGIUM

Properties and Composition of Glass determined by Flow Measurements

By P. GILARD, Jr. (From *Revue Universelle des Mines*, 9th Series, Vol. 8, No. 8, August, 1952, pp. 320-324, 14 illustrations.)

Glass subjected to localised heating shows a permanent deformation due to viscous flow, which can be determined by measuring the birefringence value. The latter varies as a function of heating time and temperature, and also depends on the composition. It is of interest, therefore, to consider the possibility of using birefringence measurements as a rapid means of assessing, without delicate equipment and at relatively low temperatures, the composition of glass specimens.

WHEN a small portion of a glass plate is heated and rapidly raised to a temperature below the critical value T_a at which structural changes occur, the temperature gradients in the material produce compressive stresses in the heated region and tensile stresses outside this region (see Figs. 1 and 2). After cooling down, the elastic stresses disappear and the glass shows permanent deformations.

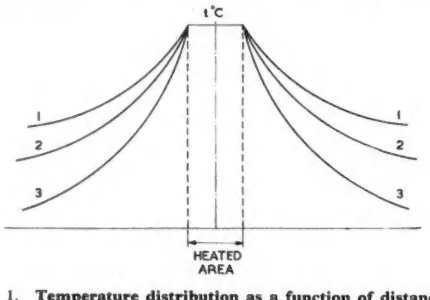

Fig. 1. **Temperature distribution as a function of distance along the plate for various heating times (Curves 1, 2 and 3).**

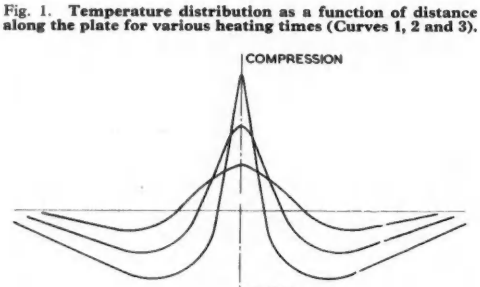

Fig. 2. **Curves showing variation of stress distribution.**

The test arrangement used for the investigation is shown in Fig. 3. The specimen, a drawn glass plate of square or circular shape, with a side length or diameter of about 30 cm, was heated in its central portion by

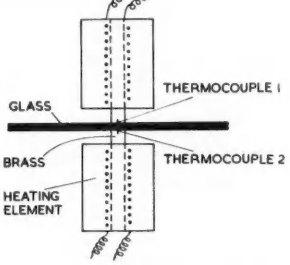

Fig. 3. **Test arrangement.**

heating elements, placed on either side of the specimen. Each of these elements consisted of a cylindrical brass rod covered over most of its length with electrical resistance windings insulated with refractory cement.

Contact temperatures were determined by means of thermocouples soldered into the ends of the bars. To avoid a sudden thermal impact, small asbestos discs were inserted between the heating elements and the glass. The discs were subsequently removed when the glass reached a fairly high temperature and the bars were then in direct contact with the specimen.

The deformations and birefringence values of reheated glass are small (of the order of 5 mμ/cm for glass heated for one hour at 320 °C), but appreciably higher values are obtained for glass specimens with a residual tempering, such as mechanically drawn glass used for windows.

The test temperatures were between 250 and 470 °C, for window glass with a critical T_a-temperature of about 490 °C. Tests of glass specimens made by the same manufacturing process but with different sodium contents gave a clear indication of the difference in composition. The birefringence variation with the sodium content follows a linear law, with, for instance, $B = 60$ mμ/cm for 12·5 per cent Na_2O, and $B = 118$ mμ/cm for 15 per cent Na_2O.

However, owing to considerable scatter, the method is not readily applicable where a high degree of accuracy

is required. For window glass for instance, it is required to detect a variation of 0·1 per cent in Na_2O. Moreover, to avoid parasitic effects due to structural variations and different tempering conditions, it is convenient to use reheated specimens, which give smaller birefringence values.

The brittleness of carefully reheated glass is probably due to the variations of Hooke's coefficient and the variations of the ultimate rupturing stress when glass is in a condition between the α-state and the stable β-state at lower temperature. It is thus necessary to distinguish the deformation due to viscous flow from that due to structural transformation. It has been shown experimentally that it is hardly possible to detect the existence of a structural change by density measurements, whereas birefringence measurements already give appreciable variations, as indicated in the following table.

COMPARISON OF DENSITY AND BIREFRINGENCE MEASUREMENTS FOR GLASS SPECIMENS SUBJECTED TO ISOTHERMAL TREATMENT.
(ρ = density [g/cm³], and B = birefringence [mμ/cm]).

Heating time	(hrs)	0	½	1	24
t = 300° C	ρ =	2·4938	—	2·4939	2·4941
t = 316° C	B =	0	41·0	—	—
t = 400° C	ρ =	2·4935	—	2·4943	—
t = 400° C	ρ =	2·4940	—	—	2·4977
t = 412° C	B =	0	275·0	—	—
t = 450° C	B =	0	450·0	—	—

The disparity between the large birefringence values and the density variations which should characterise any changes in structure is clearly apparent from these results. The explanation which can be inferred is that the viscosity of α-glass is greater than that of β-glass, at similar temperatures.

Experimental evidence of the plastic deformation of glass at temperatures approximately 200 °C below the transformation temperature was obtained from photographs of the drawn-glass specimens with an incident light at 45 degrees to the glass surface, the reflections from the other surface being eliminated by suitable means. Instead of parallel lines in the direction of drawing, the lines obtained curved around the heated region. The bulging of the plate was found to correspond to a light spot, due to divergence of the light rays, on the photographs of the upper surface, and to a dark area, due to convergence of the rays, on the lower surface. Confirmation of the bulging was obtained by observing the interference fringes appearing between the deformed plate and anoptically flat surface, with ring patterns around the peak position on both surfaces.

This bulging occurs because the heated portion of the specimen is unable to expand laterally owing to the resistance of the relatively colder glass surrounding it, so that expansion has to take place in the direction of the glass thickness. The large bulge which remains after cooling is characteristic of viscous deformation. If there was a structural change in this region, there should be a hollow position in this region, since increased density corresponds to a reduction in volume. Thus, the residual bulge obtained after cooling down indicates that the viscous flow effect is greater than the effect of structural transformation.

GERMANY

Methods and Apparatus for Determining the Dust Content of Flowing Gases

By P. Noss.* (From *Brennstoff-Wärme-Kraft*, Vol. 4, No. 7, July, 1952, pp. 227-233, 10 illustrations.)

Most dust measurements are carried out in order to determine chimney output, fuel utilisation or the efficiency of dust-separation plants. The increasing use of pulverised coal firing systems and the correspondingly more stringent guarantees required for purified gases make it even more necessary than previously to have accurate dust measurements.

Rules for performance tests of gas purifiers and rules for the determination of dust composition based on grain size and settling velocity have been issued by the V.D.I. Panel for Dust Measuring Methods. The requirements of theory are not easily fulfilled in practice, for instance, in horizontal flue gas ducts, so that measurements in chimneys are generally preferred in spite of effects due to wind direction and sedimentation.

The quantities which generally have to be determined in flowing gases are (1) the dust density [g/m³] or dust flow [g/sec]; (2) the grain size; and (3) the chemical composition of the dust.

Dust measurements involve three operations, viz., the extraction of part of the gas flow, dust collection from the extracted gases, and flow measurement. The results are affected by a large number of factors, such as the velocity distribution, dust density, grain size, material and chemical properties of the dust, humidity of the gas, etc. The measuring methods are, therefore, compromise solutions based on practical experience.

EXTRACTION OF GASES FROM THE MAIN GAS FLOW

Continuous sampling of the gases is achieved by means of a probing unit or suction tube placed in the main gas flow. This unit measures gas pressures or velocities and also transmits a test stream, i.e., a portion of the flowing gases, to the dust collectors for subsequent analysis.

The primary requirement is that equal velocities be obtained in the test stream and the main gas flow. Particularly when extracting dust particles with a wide range of grain sizes, any difference in velocity between the main gas flow and the test stream passing through the probing unit may alter the relative distribution of grain sizes and lead to measurement errors.

Generally a set of suction tubes is available for the tests, with inlet diameters varying according to the range of flow velocities considered. The probing unit must in all cases be of a size which allows it and its associated apparatus to be completely surrounded by the gas flow. There are two basic types of probing units, viz., the zero-pressure and the velocity type, and some typical designs will now be considered.

A zero-pressure type probe of the Van Tongeren type is produced by the firm Rosenmüller of Dresden (see Fig. 1). The pressure orifices in this unit lead to two separate pressure chambers which communicate with the tubes of a manometer arrangement. When the static pressures of the test stream and the main gas flow are equal, the corresponding flow velocities are also theoretically equal, and representative measurements are then possible.

A probing unit which can be used for dust content

*From a paper presented before the V.D.I. Dust Technology Committee at Gelsenkirchen.

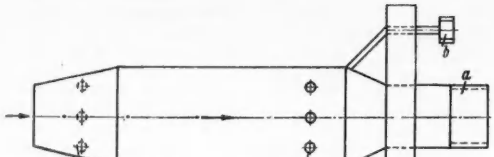

Fig. 1. **Zero-pressure type probing unit (Van Tongeren design).**

a = Connection to holding tube; *b* = connections for zero-pressure indications; *c* = static pressure in main gas flow; *d* = static pressure in test flow.

determinations in stationary or slowly moving air has been developed by the firm Gothe of Bochum, in conjunction with the Bochum Silicose Research Institute (see Fig. 2). It gives both zero-pressure and flow velocity indications.

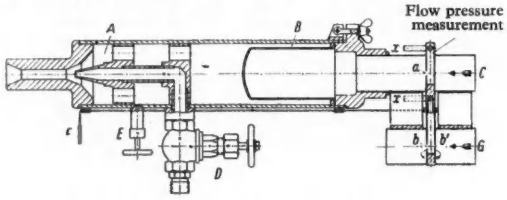

Fig. 2. **Dust measuring unit (design Gothe).**

A = Injector; *B* = cloth filter; *C* = suction tube; *D* = rough control; *E* = fine control; *F* = actuating system for flow-pressure measurement; *G* = comparator.

a = Passage in flow velocity indicator; *b* and *b'* = orifice positions of indicator in comparator; *x* = rubber tube connectors.

The unit comprises an injector *A* (operated with compressed air at 4-5 atm (57-71 psig) controlled at positions *D* and *E*) and aspirates the gas through the probing element *C* and a cloth filter *B*. A comparator cylinder *G* which is identical to *C* in size and shape is situated at a distance of 5-6 cm parallel to the latter. Both tubes communicate with the pressure indicating apparatus through the connecting stubs *x*. The main probing element has a pressure orifice *a* situated in a transverse tube on the downstream side. The comparator element *G* has a similar small tube which is bored through and provided with a rotatable sleeve having an orifice which can be turned either into the downstream or the upstream direction by acting on a controlling arrangement *F*. For pressure measurements, the orifice positions *a* and *b'* are used, pressure differences being indicated by a spring-compensated vane type flow-meter. When the flow-meter pointer indicates zero pressure difference, the flow velocities of the two gas streams are equal. The control sleeve of the comparator element is then rotated to the orifice position *b'* to obtain a velocity measurement. The total gas flow is determined from the test stream velocity and the ratio of the cross-sectional areas. The apparatus is of simple and robust construction, and can be brought into horizontal channels by means of a holding tube. It should be calibrated before, and preferably also after, each test.

A French design of dust-measuring apparatus, produced by the Prat-Daniel Co. of Paris (see Fig. 3), combines in a single probing unit the suction tube, dust filter and a measuring orifice. Suction is obtained by an injector or a Roots' blower. The apparatus is of the zero-pressure type. As the entire unit is subjected to the temperature of the burnt gases, there is no loss of dust between the suction tube and the filter. The apparatus is about 50 cm long, and is claimed to be particularly suitable for small plants with gas temperatures up to 180° C.

A velocity type probing unit developed by the Babcock Co. of Oberhausen/Rheinland (see Fig. 4) measures static and dynamic pressures in the same way as a pitot tube by means of four lateral orifices *b* on the outer cylinder and four small tubes arranged externally. The unit includes a nozzle or orifice plate for test stream measurements and can thus indicate differential pressures at various positions.

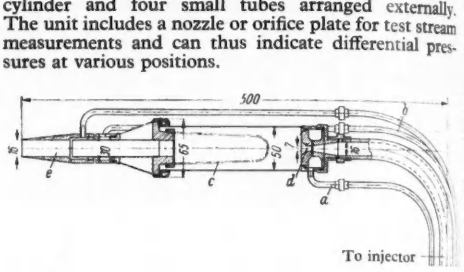

Fig. 3. **Dust measuring unit (design Prat-Daniel, Paris).**

a = Measuring tube for nozzle; *b* = zero-pressure tubes; *c* = dust filter; *d* = standard venturi tube; *e* = suction tube.

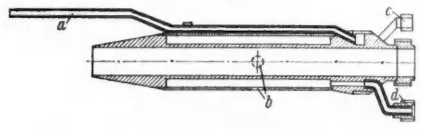

Fig. 4. **Velocity-type probing unit (Babcock).**

a = Four measuring tubes for total pressure in main gas flow; *b* = four orifices for static pressure in main gas flow; *c* = connection for total pressure; *d* = connection for static pressure.

With zero-pressure instruments the flow velocity at the measuring position has to be determined with a static tube in a subsequent measurement. The velocity type apparatus gives direct measurements of flow velocity during the extraction of the test stream. Before or after the main test, it is useful, however, to check the mean flow velocity either with the same probing unit or with a static tube.

The investigations of the V.D.I. Panel for Dust Measurements showed that the velocity type probing units can be given a Class I rating, whereas the zero-pressure probing units of the Van Tongeren type tend to indicate smaller values than the actual ones for the test stream. This may be due to a shedding of the flow near the pressure orifices. It is probable that similar effects occur with other zero-pressure types of equipment. The results could be related to a calibration curve giving the zero-pressure correction for various values of mass flow velocity.

The following factors may tend to limit the accuracy of results obtained with probing units :—(1) the size, weight, and surface finish of the probing units, particularly at low velocities; (2) possible leakages in screwed joints and connections; and (3) damage which may occur to the suction tube during its insertion in narrow passages, with holding tubes which frequently reach lengths of 3-6 metres.

DUST-COLLECTING APPARATUS

Comprehensive dust collecting equipment is essential for dust measurements involving grain size determination. The aspirated dust is passed through a cyclone or eddy chamber, in which the coarse dust particles are precipitated. The finer dust remaining in the flow is then collected in filters. The possibilities of cloth filters are not generally appreciated and particularly interesting results have been obtained with pure woollen filter fabrics. The resistance of a cloth filter, unlike that of a paper filter, is not appreciably affected by increasing dust deposits, and with the fabrics

previously mentioned it has been found that the dust quantities retained are not greater than with paper filters. Provided the cloth filter is carefully emptied, the dust loss and grain pollution is generally negligible.

TYPICAL INSTALLATIONS

The installation generally comprises a suction tube, a collecting system and measuring equipment. Experience has shown that it is preferable to separate the suction tube from the collecting unit, which can be mounted externally. Gas conditions are measured at the throttling position and the suction position. It should be noted that gas meters are not very suitable for furnace gas measurements.

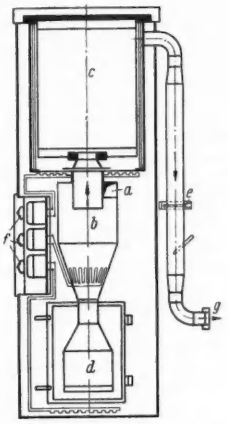

Fig. 5. **New Babcock dust collecting unit.**
a = Test stream inlet; *b* = cyclone; *c* = cloth filter; *d* = dust collector; *e* = calibrated orifice for test stream; *f* = switch for electric heating; *g* = connection to injector.

The Bewag equipment, developed before the last war, comprises a zero-pressure probing unit with an injector arrangement, which takes the test stream through a holding tube into the collector which is followed by a standard measuring orifice. Preliminary precipitation is obtained in a cyclone formed by a conical insert inside the collector unit. The dust enters this chamber tangentially and the coarser particles are precipitated before the flow reaches the paper filters mounted on wire gauze. The measurements include determinations of velocity at the suction position by means of a static tube, and a gas analysis for density determination. The conditions at the measuring position and the orifice position are investigated by measurements of pressure, temperature and humidity. The holding tube and the collector can be electrically heated. Although the removal of the dust from the filters with minimum losses and without altering the grain sizes is extremely difficult, the Bewag equipment has been found to give good results and is still in widespread use. The various components should be dismantled and inspected before and after each measurement.

The pre-war Babcock equipment has been improved by arranging the cloth filter system over the cyclone precipitator in a single casing. The improved design has a low instrinsic resistance and a high flow rating of up to 100 m³/hr. The apparatus incorporates a velocity type probing unit. In order to determine the gas flow, the dynamic pressure must be recorded at regular intervals during the test. The suction tube is also designed for static pressure measurements. This equipment has been found to give very satisfactory performance.

The new dust measuring installation produced by the firm Rosenmüller of Dresden (see Fig. 5) retains some of the features of the Bewag equipment, but is of more compact design. The four or six plate filters originally used are replaced by a round filter having approximately the same area and the measuring orifice is situated in the purified gas stream. The new filter arrangement is an improvement as regards the extraction of the aspirated dust, but the sealing arrangement requires checking at regular intervals. The equipment includes a cyclone precipitator and a collector unit which can be heated if necessary.

EXPERIMENTAL DATA

As a result of practical experience, the following findings are of importance in connection with dust measurements.

(1) At a suitable position for flow measurements (e.g., in a section of a chimney), the velocity distribution is continuously subjected to small disturbances, but the mean velocity and the gas flow will remain practically constant, provided that the boiler load and the type of fuel used are unchanged throughout the test.

(2) As long as the gas flow velocity in a vertical gas stream is greater than the rate of fall of the dust particles, the maximum dust density will probably be on the side where the velocity is greatest. This assumes, of course, that any flow disturbances in the ducts, due to sharp bends or throttling, are damped out by the time the gases reach the measuring position. In horizontal channels the relation between flow velocity and density still applies, but to a lesser degree. Moreover, as, in this case, the falling velocity is at right angles to the direction of flow, there is a tendency for heavier dust particles to settle at the bottom of the channels. The magnitude of this effect depends on the ratio of the height of fall to overall distance, as well as on the flow velocity, density and viscosity of the dust. It is therefore preferable to arrange the measuring position in a vertical passage.

(3) The alteration in grain size distribution when the suction velocity is not kept constant is overestimated, particularly for fine dust particles of fairly uniform grain size, according to our observations and those of Zimmerman, Lüth and Guthman. For practical purposes, fine dust in a moving gas can be regarded as an aerosol, which is hardly affected by the laws of gravity. This finding makes it possible to base the suction measurement on a previous measurement of the dynamic pressure head obtained with the same probing cross-section, provided stable flow velocity conditions are maintained. The main objects of the test are then dust collection and velocity of flow determination.

The above findings are generally valid. They also indicate the possibility of using a simplified method for dust content determination when it is required to measure very small quantities of dust having an extremely fine grain size, for instance, in purified flue gas or gas from a highly efficient dust extractor. All that is needed is a set of simply designed suction tubes containing small-size ceramic or press type filters, and the velocity of the test stream can be determined with a gas-meter, since it has a sufficiently low value. In many cases, this equipment is sufficient for approximate indications.

CALCULATION OF FLOW IN THE TEST STREAM

It is first necessary to calculate the effective pressure at the throttling device (calibrated orifice or nozzle). Let T_F and p_F be the temperature and pressure conditions in the main gas flow (in °K and mm Hg), T_0 and p_0 the corresponding values at the throttling orifice, h_F the dynamic pressure head (in mm of water) of the main gas flow, C a constant of the throttling device

($C = Q/\sqrt{h/\gamma}$ with Q in m³/hr), and d the diameter (cm) of the suction head. Then the effective pressure p (in mm of water) at the throttling device is obtained from

$$p = 1{\cdot}568\, d^4\, h_W\, p_E\, T_0/(C^2\, T_E\, p_0).$$

Since the state of the gas in the chimney remains generally constant, the only variables are p_0 and T_0. These are affected by the cooling or heating of the collector and the flow resistance of the entire apparatus, including the rubber-tube connections and the filters.

Although the flow in the test stream is initially adjusted without taking account of gas density (γ), it must be calculated using the equation for the throttling device. The dust content is then determined and the quantity of dust flowing per unit time is plotted for the corresponding value for the furnace gas. The results can be checked by verifying that the figure for the total gas flow per second is in agreement with the value obtained by multiplying the flow in the test stream by the ratio of the cross-sections of the main flow and the probing unit.

The effect of humidity on gas density can be neglected for dew point temperatures below approximately 40 °C, for the range of absolute pressures occurring in practice at the measuring orifice, and the gas density calculation can then be based on pressure and temperature only. The error thus appearing in the gas flow evaluation is of the order of 1-2 per cent. It increases considerably, however, with higher dew point temperatures, and the results then show too high values for density, dust content and dust quantity ejected, while the calculated flow velocity is lower than the true value. Thus, for a dew point temperature of 80 °C, the neglect of humidity in the density calculation results in a calculated value for flow density which is 12 per cent too low.

OVERALL EFFICIENCY OF DUST-EXTRACTING EQUIPMENT

The efficiency η of a dust-extracting system is determined as the ratio of the weight of dust removed W_{dr} to the weight of the dust W_{un} contained in the unpurified gas. Taking also into consideration the weight W_{pu} of the dust remaining in the purified gas, it is apparent that n can be determined from simultaneous measurements of either W_{dr} and W_{pu}, or W_{dr} and W_{un}, or W_{pu} and W_{un}, by means of the following relations :—

$\eta = W_{dr}/(W_{dr} + W_{pu})$ (Method 1)
$\eta = W_{dr}/W_{un}$ (Method 2)
$\eta = (W_{un} - W_{pu})/W_{un}$ (Method 3)

It is of interest to consider the effect that errors in the determinations of these quantities have on the overall dust-removal efficiency :—Errors in the same direction compensate each other in methods (1) and (2), but are additive when method (3) is used.

Method (1) is preferred for technical reasons. The quantity of dust removed can be reliably determined by weighing, taking due care to avoid disturbances during dust removal. Unfortunately, this method involves some difficulties in the grain size determination. Grain size is a criterion for the effectiveness of any given dust-eliminating system, and the grain size of the unpurified gas has to be calculated from that of the dust removed. As regards grain size determination, therefore, this method is open to the following objections :—(1) the extraction of an average sample (3-5 grammes) which is truly representative of the dust removed is difficult and uncertain ; (2) the dust collector unit, particularly in mechanical purifying equipment, may not contain all the sizes of dust removed ; and (3) the grain sizes may be polluted by the blower in the suction head and this will then also affect the grain sizes in the purified gas.

DISCUSSION

The following contribution to the discussion of the above was made by K. Guthman, at the V.D.I. Dust Technology Committee meeting of 1951 at Gelsenkirchen.

Dust measurements are not only required in dust-extraction plants used for air purifying but also are particularly important in recuperating plants where valuable dusts are recovered from burnt gases, and in fine purifying plants for industrial gases used for heating purposes.

Producer and blast furnace gases are required to have a dust content not exceeding 10 mg/m³ at N.T.P. after passing through a purifying plant. The dust content of blast furnace gases is subjected to extremely careful supervision, and is an important economical factor, since each blast furnace produces 1-2 million cubic metres of gas per day. In this type of work, the measurements cover both the unpurified gas, from which the coarser grain sizes have to be removed, and the purified gas, which contains very small dust quantities (less than 20 mg/m³). This dust is highly dispersed and generally smaller than 1-2 microns, so that in effect it has the properties of an aerosol.

Measurements in large iron works are particularly difficult. The measuring positions are generally in highly situated gas ducts, near dust collectors, cyclones and purifying plants. Owing to its high CO-content (about 30 per cent), the blast furnace gas is very poisonous so that special precautions are required in taking measurements. Large and heavy measuring equipment cannot be used. The suction ducts are frequently of considerable length, and require water cooling or electric heating. All the equipment must be extremely sturdy and easy to handle.

For these reasons, the dust-measuring devices in iron works are of an extremely simple design, which has been considerably improved recently by the Heat Research Station, at Düsseldorf, of the German Metallurgical Society (VDE), and the equipment fulfils all requirements. Measuring units of the Bewag, Rosenmüller and Babcock types have been found too large for use in blast furnaces.

The extracted quantities of dust have to be weighed together with the paper filter, which is, however, hygroscopic. It is more suitable, therefore, to reduce the filter to ashes with the extracted dust. The dust content S of the gas (in mg/m³ at N.T.P.) is then calculated from

$$S = a \times 100/[(100 - b)\, V_a]$$

where a = weight of dust and filter-paper ashes, in milligrammes, b = combustion loss of the dust, as a percentage of dust weight, and V_a = the quantity of gas from which the dust sample has been extracted, determined, for instance, in a gas meter in m³ at N.T.P. For the determination of the combustion loss of the dust, it is essential to use a dust sample taken from the dust extracted from the measuring position. Regarding filter paper, it may be mentioned that good results have been obtained with the 11-cm filter paper No. 589 of Schleicher & Schüll, which has an ash weight of 0·07 mg.

For dust contents above 3-5 g/m³ at N.T.P. it is a basic requirement that the suction velocity of the test stream should be maintained equal to the main flow velocity throughout the test. For gases with lower dust contents, and particularly for fine purified gases with dust contents below 20 mg/m³, this requirement is not so important. According to the investigations made by Zimmermann, the measurement error for a test stream velocity somewhat higher than that of the main gas flow is less than that obtained when the test stream is at too low a value. In all cases, it is important to measure the flow of the test stream accurately, since an error of 10 per cent in this measurement will also give a 10 per cent error in the dust content, whereas a discrepancy in velocities, particularly for fine-size purified gas, has a much smaller effect.

Welding in the Soviet Union

By J. MANNIN.

In his series of articles on mechanical technology in the Soviet Union, the author reviewed in the last two issues of this journal the technical history and special characteristics of metal cutting machinery and processes as well as recent advances and current trends in this field. In this issue he deals with the technology of joining and severing of metals by the local application of heat and pressure. It is common practice to classify the whole of this field under the heading of "Welding."

No one studying Russian technical literature in any branch of engineering can fail to perceive that Soviet Authorities attach special significance to welding technology. It is worthwhile for our purpose to examine briefly some characteristic features of welding.

Welding in the forge by the hammering of low-carbon steels in the hot state is among the oldest forms of metal working, certainly as old as chains. In the modern era the predominant welding process is fusion welding, in which local melting is achieved by applying a source of high temperature. Such sources of heat were unknown before the second half of the nineteenth century and hence welding in the modern sense is a young technique.

The older industrial countries did not, therefore, possess an advantage by having a large reserve of skilled craftsmen backed by the traditions of several generations, in contradistinction to other fields of engineering. This state of affairs was partly responsible for welding techniques having to be content from the start with relatively simple skill.

However, welding technology and, in particular, the technology of fusion welding and allied processes was also attended by another peculiarity when it burst upon the industrial world. Not only the skill but also the equipment needed for welding were relatively simple. Fusion welding was one of those occasional reversals in the trend of industry towards larger and more exclusive production machinery. It became the "little man's" tool and if, in the early days, welded structures could not often compete with castings in engineering, many staunch individualists with small overheads made welding competitive and literally carried the torch of independence. Indeed, one branch of welding technology, namely, oxygen cutting, is said to be largely due to the initiative of those supreme "individualists," the safe-blowers.

In the Soviet Union, the low standard of skill required and the simplicity of equipment made welding attractive. The common idea of the Soviet Union is not usually associated with individualists, but, in fact, a special kind of individualism is highly characteristic of Russia, namely, isolation through remoteness.

Special conditions prevailed in the Soviet Union after the First World War and the Civil War. Reconstruction was often a task of repair. An example of the same task after the Second World War in the regions overrun by the Germans is instructive. "Scorched earth" activities and sabotage of railway tracks mostly took the form of cutting out small lengths of rail at intervals. In planning the reconstruction of tracks, it was realised that vast quantities of rail would be saved if butt-welding were used in repair. Thus, the Soviet Union became the first country in the world with really large stretches of welded railway track, although trial welded tracks had existed for a long time in other countries and some welded tracks in undeveloped countries with low traffic density were operated before the war.

Perhaps the main incentive to develop welding technology was the unattractiveness of alternatives. In Great Britain a visitor to the Clyde or the Tyneside around the time of the first World War, was deafened by the infernal noise of thousands of riveters. Today he is more likely to be blinded by welding arcs, but the process was gradual and, if anything, the enforced idleness of the tremendous highly skilled army of riveters during the depression was a major tragedy of industrial Britain.

In the Soviet Union, at the beginning of industrialisation, the choice was between the acquisition of an old and complicated skill and the development of a young and somewhat uncertain technique. The Soviet authorities did not adopt either alternative completely, but a heavy bias existed in favour of welding.

The patriotic neurosis which has characterised all Russian public pronouncements in the last two or three years has laboured the theme of Russian priority and superiority in welding technology *ad nausea* to the exclusion of a sober assessment of real achievements, shortcomings and tasks. In these years, we have to dig for information at the level of specialised technical studies, practical reports, recommended codes and standard specifications. However, in the immediate post-war years, critical thought was allowed to appear in the more general pronouncements by the technical leaders of the industry.

An example of balanced, penetrating thought can be found in an article published at the beginning of 1947. The author recognises that at the time of writing, much of the production arc welding practised in the Union was at a lamentably low technical level. The design of welded structures bore the symptoms of "illegitimate birth" from riveted construction. The contrast between this state of affairs and the indisputably remarkable achievements in the front rank of fusion welding is explained by what, in Soviet idiom, are called the "internal contradictions" of the welding process.

Welding technology operates on metallic material, but it is employed mainly in the metal-working and assembly stages of the production sequence, and its aim and result are the manufacture of a finished assembly. Hence, welding achieves the tasks of mechanical technology by means of metallurgical processes. The second peculiarity of welding technology is that, though a basic process, it never becomes a controlling process. The third characteristic feature of welding is that its performance is founded on several kinds of phenomena, usually belonging to different technical sciences. Thus, welding by its very nature endows the large enterprise operating in several spheres of technology with an inherent advantage in developing its techniques. The history of welding in Russia (and elsewhere) has proved that the advantage is a marked one. In the Western countries we have witnessed the fact that whilst the *employment* of welding has been a favourite playground for the little man, the *development* of welding was left to the manufacturers of welding equipment and auxiliary materials.

Our Soviet welding philosopher of 1947 comes to the same conclusions, and in Soviet terms asserts that research, organisation and production of equipment and materials are the tasks of central establishments. In this context, his remarks show that if the choice to force the development of welding at the beginning of Soviet industrialisation was a wise one, it certainly was not an easy one. Much effort and clear-sighted direction were needed to allow welding technology to take up the position in mechanical and structural engineering for which it was destined according to the Soviet scheme of things. The form which this effort took is most typical of Soviet industrial progress, but nothing short of blindness could justify a denial that the success of the effort is at least adequate and at times outstanding. Soviet welding technicians have some justification for pride. Unfortunately, in their less sober moments they are

apt to forget that an autonomous industry, like the strength of a chain, is governed by its weakest link. In a comparison with welding in the Western World, Soviet industry must be judged by its omissions as well as by its showpieces.

Modern welding entered the industrial scene around the turn of the century, but made no great inroad in Russia until after the Revolution in 1917. Like most industrial developments, welding received its decisive impetus in 1929, at the beginning of the first Five-Year Plan and the period of forced industrialisation. Since then, the welding community in the Soviet Union has arisen as a microcosm reflecting all Soviet tendencies to the full and, indeed, a somewhat cosy microcosm be-because it happens to be relatively free from the cataclysmic purges at the top, probably owing to its success in essentially fulfilling the tasks allotted to it.

This world has its own mythology, temples and doctrines. Its saints are the early Russian inventors of arc welding, one of whom was even " sporting " enough to be called Bernardos. He was the inventor of the carbon arc process, and henceforth his name must be mentioned by everyone who talks of carbon arcs. More important than this harmless pursuit are the central institutions of welding technology. Here we find the same sequence observed in other branches of Soviet industrial development. Perhaps the most progressive and far-sighted aspect of Soviet advance is that it commences with institutions of teaching and learning. In the welding world we find that a welding polytechnic was established in Moscow in 1930. This was followed by the Institute of Electric Welding of the Ukrainian Academy of Science and the Central Research Institute attached to the Ministry of Transport Machinery which established an Institute of Electrical Welding. A Society of Welding Engineers was formed in 1930, and the periodical " Avtogennoye Dyelo " (Welding Trade) commenced publication in 1929. The same two years saw the first batch production of equipment for electric arc welding, notably the welding transformer for a.c. welding units, put on the market by the " Electric " factory. Production of an ever-increasing range of standard coated electrode material was commenced. The issue of equipment for acetylene gas welding and oxygen cutting was a gradual but equally decisive development. A research institute all of its own did not exist until after World War II. The design and production of original spot welding machines and other equipment for a variety of resistance welding processes was begun.

Research into ways and means of increasing the productivity of welding labour and reducing its skill was not long delayed when it was found that welding operations did not lend themselves to a speed-up by will-power and ingenuity in the deployment of labour and administration of incentives which characterised the productivity drive associated with the name of Stakhanov. The arc welding process appeared to be limited to a maximum speed owing to the inability to introduce more electrical power into the arc without destroying the quality of welds. Among the research projects conceived, the persistent and purposeful effort directed at the Ukrainian Institute under the guidance of that grand old man I.O. Patton finally produced the automatic welding procedure characterised by an arc burning under a pile of granulated flux, to which we shall return below as one of the triumphs of Soviet welding technology.

At present, the welding industry in the Soviet Union produces most of the welding equipment known in the U.S.A. and Western Europe. In electric arc welding, d.c. welding generators and a.c. transformers are available, though the latter predominate by far. Single-point and multi-point units are produced for both d.c. and a.c. welding. Stationary and portable converter units for electric drive as well as engine-driven self-contained aggregates are built. D.C. generators are mainly of the split-pole type, though the " Lincoln Electric " system of counter compound windings is also practised, and the combined system (" Paradine ") is also home-produced. The original mass-produced welding transformer with built-in reactor winding is claimed to be a Russian invention. This is now supplemented with equipment using separate reactor coils. On a small scale, high-frequency oscillators and welding rectifiers have also emerged into industrial use.

Electrodes with a thin and thick coating are standardised. In 1947, electrode standards included five items of thinly coated electrodes for arc stabilisation, used mainly in the welding of thin-gauge low-carbon steel and about sixteen items of thick coated electrodes carrying a flux coating and fulfilling the many needs of the arc welding of various materials. This list compares with the American A.S.T.M. classification which recognises about 50 items. Since 1947, several new types of electrodes have been added to the Soviet catalogue in answer to specific demands and after exhaustive investigations.

Carbon arc welding is carried out with graphite electrodes, and electric arc cutting with graphite and metal electrodes is practised on a small scale in the Soviet Union. Complete equipment for atomic hydrogen welding is made in Russia for supply from stored hydrogen or from an ammonia dissociator producing a hydrogen-nitrogen mixture. Home-produced equipment for argon arc welding with tungsten electrodes has recently been made available which roughly follows Western practice, and its use appears to be rapidly spreading.

At the expense of the dominating role which automatic welding on the submerged arc principle has assumed in Russia, all other processes of automatic welding, such as that with coated electrodes, continuous electrode wire and other proprietary systems of German, British or U.S. origin, have been almost completely neglected. The allied processes of brazing and soft soldering are admitted in Soviet publications as having been sadly and undeservedly neglected until this day.

However, the relatively easy conditions which the carbon arc offers for automatic control has induced Soviet engineers to develop semi-automatic heads for carbon arc welding with saturated paper welding pool protections. The Lincoln-Electric fully automatic (" Tornado ") machine has a Soviet counterpart.

Gas fusion welding is practised on a large scale in its appropriate fields, assessed roughly by the criteria prevalent in the Anglo-Saxon countries. The whole range of oxygen and acetylene-producing or storing devices in current use here is employed in the Soviet Union. It would appear that the carrying of liquid oxygen is more favoured in Russian than in Western practice. Shops using oxygen carried in liquid form require evaporators, low-pressure and high-pressure types of which are supplied by Soviet factories. A large variety of acetylene generators of standard design is available. Burners for welding and cutting are home-made to a standardised design.

The use of flame hardening is in its infancy, and special machinery is not available. In oxygen cutting, the whole range of cutting operations is practised, including all oxygen machining processes, particularly surface cleaning and cutting of grooves. Cutting machines are made of automatic and semi-automatic types, both portable and stationary. The variety of copying machines is much less wide, and the principles employed in the guidance of the cutting head are much less numerous, than those used in American industry. In 1947, only two types of cutting machines were in batch production, one of which was intended mainly for the chamfering of edges in preparation for welding.

Among electric resistance welding machines, the butt welding field is well covered by about 15 types and

sizes of original Soviet design embodying various means of feeding, clamping, switching and actuation. No flash butt welding machine was available in 1949.

Nine sizes of normal spot welders of Soviet manufacture are offered. A portable spot welder has been developed, but no small single-electrode apparatus. An original design of a projection welding machine and five sizes of normal seam welders are in existence. In the seam butt welding of electrically welded tubes, the Soviet Union is following in Western footsteps. Spot welders with impulsive release of stored energy are as yet lacking. Special electrode alloys and arrangements have been introduced.

Gas-butt welding for the joining of pipes in overland high-pressure pipe lines was introduced after the importation of U.S. equipment following the war. Original machines are now available.

The range of materials currently welded in the U.S.S.R. is extensive. The difficult materials, like stainless steels, " chromansil " type steels, heat-resisting steels, and aluminium and magnesium alloys, have been brought under control by various means such as special electrodes, argon shielding, and flux combinations. In this matter, Soviet technology often registers advances which can be profitably studied over here. Some will be mentioned in the following.

In the application of welding, Soviet engineers have done much pioneering. Railway track repair has been mentioned above. The first completely welded large-span rail bridge was built in Russia. The use of welding in rolling stock manufacture was practised on an extensive scale several years before it was generally adopted elsewhere. Under-water welding and cutting has been in use for many years. On the other hand, spot and seam welding in motor car production is behind Western practice. The great revolution in shipbuilding through the introduction of all-welded liberty ships is an American innovation. Oxygen cutting in the mass production of profiled components made from steel plate was also originally an American practice. There are no signs of a particularly thorough examination of welded machine tool housings in the U.S.S.R., but hard facing and welding of tipped and composite tools are greatly in evidence. Among outstanding Soviet achievements and recent advances, the technique of automatic arc welding occupies a special place. The assertion of originality is argued with unnecessary heat. The Soviet achievement is without doubt an original development. The equipment created for carrying out this process has an unequalled range and refinement of detail. The understanding of the process and of the metallurgical, mechanical and electrical factors affecting it, and the knowledge gained of the means for its control are unique. Only a qualified court hearing could establish priority in accordance with the traditional interpretation of some specific patent code. Most engineers will agree that such a ruling would hardly diminish or enhance the prestige of either side. The Soviet case is much stronger if they point out that anybody can have an idea which turns out to be right, but few can muster the ability and tenacity to make a practical industrial process out of an idea.

Mechanisation of arc welding can increase productivity by a factor of 1·7 to 2. A further increase is only possible when the power of the arc is increased. For this the arc must be submerged. Granulated flux has been found a suitable medium. By means of a circulation system, flux powder is spread over the seam ahead of the arc, and that part of the flux which has not been melted and deposited as slag upon the welded seam is sucked back into the circulation system behind the arc. The American " Union-Melt " process is essentially similar. Increases in productivity through high speed of advance along the seam can reach a factor of 20.

The submerged-arc process can utilise a d.c. or an a.c. arc, usually the latter. The open-circuit voltage of the welding transformer can be high or low. The electrode, which is a bare wire, can be fed with constant speed or varying speed to maintain a constant arc length. Filler wire may be used, in which case the arc burns between electrode and filler wire. The submerged arc process raises productivity, saves electrode material and power, simplifies control and dispenses with skill.

Its operation requires elaborate equipment, a flux circulation system, flux guards, electrode (and filler wire) feed mechanism and welding head traverse mechanism. Welding heads are classified by the provision or omission of automatic traverse and constant or variable rate of wire feed.

Both the Ukrainian and the Russian Institutes for electric welding have developed a series of welding heads, and more complete units known as tractors of the automatic and semi-automatic types. There are also portable units, suspended units, travelling crane units, and others. A variety of ingenious flux guards and other accessories are described.

Any but straight, horizontal seams need machines for manipulation of heavy components. An impressive variety of special and universal machines for the generation of precise motions of components has been created for use in engineering and structural welding shops. Almost every variety found in machine tools is repeated.

The development of submerged-arc welding techniques continues. Certain basic trends can be recorded. Perhaps the most important is the 3-phase arc welding head. The component is connected to one phase in a 3-phase system and two electrodes are connected to the other two phases. Striking improvements have been obtained : a rise in productivity (doubled) accompanied by economy in electric power, higher power factor, and improvement in the quality of the seam. The success of the 3-phase system in automatic welding has led to its introduction into manual arc welding with considerable success. All advantages are obtained, though in smaller measure.

Another method of further improving the submerged process is the use of two electrodes in parallel located one behind the other. The leading electrode is straight and the following electrode inclined forward. Separate filler wire can be used. This enables more aggregate power to be introduced without excessive widths of seam and thick electrode wire. Filler wire may be used in addition. Large improvements in productivity, economies in wire, and more convenient working are possible. Welding speeds are in excess of the maximum achieved with a single forward facing electrode (150 m/hr at 2000 A).

A totally new approach is the introduction of filler material already in liquid form. This method, as yet experimental, is regarded as most promising. Another really important step is the hot-forming of the seam surface after welding with a water-cooled copper former which improves the appearance and the mechanical qualities of the seam.

By way of refinement, some recent developments insist on separate regulation of arc current and arc voltage for best seam qualities. Further demands on steel qualities are made. Welds executed under cold atmospheric conditions require " killed " steel to avoid the harmful effects of cold-brittleness on the results of welding. Two-flux operation has been tried with resultant flux specialisation and economy.

Perhaps of greatest practical importance is the introduction of very thin electrode wire (1·2 to 3 mm dia). Productivity is increased, power saved, seam quality improved, carbon content (up to 0·5 per cent) and thickness range of material (down to 1 mm) widened. But the main advantage is the ease with which a flexibly connected unit can be employed. This novelty alone, it is said, increases the range of potentially convertible manual welding from 20 per cent to 50 per cent of all welding operations in industry.

Specialised submerged arc heads and installations continue to appear. Among these, a unit for spiral welding of tube from wound strip is remarkable for its speed. A pistol for plug welding, another for stud welding, and a third for automatic welding of double curvature seams in boiler manufacture are further examples. The submerged arc process has now been successfully applied to copper and aluminium alloys.

Outside the submerged arc field, advances are made in many directions. The gaps in Soviet equipment, as stated above, are being gradually filled. Though at the time of writing, these gaps describe the industrial picture, there is much laboratory and development activity. Recent advances are concerned with widening the range of materials, replacement of welding auxiliaries in short supply, and new applications of welding. Some new developments established or under investigation are the control of spot welding by temperature-sensitive or dilatometric elements, thyratron triggering of spot welder sequence, automatic electric butt welder for rails, a new thermite composition with magnesium alloy, under-water cutting with a petrol-oxygen burner, under-water welding with carbon or with carborundum electrodes, the introduction of steel powder into arc welding electrode coating, reduction of sheet "oil canning" by pressure or by magnetic clamping, electric arc surface hardening, electric arc metallising, impulse spot welder using stored kinetic energy, and nitrogen arc welding of copper.

Research in Soviet welding laboratories is concerned mainly with the study of the welding arc, the spot formation process, distortion of structures, internal stresses and intercrystalline locked-up stresses, formulations of weldability, and improvement of seams by a post-treatment. Interesting results are rules for straightening in welded airframes, general review of automatic control in welding, rational design criteria related to process control in arc welding (including control under severe winter conditions), limitation of bending test of seams, and fatigue strength improvement by hammering. The experimental methods employed in this research are as advanced as any used in welding laboratories in Europe and the U.S.A. and, like all laboratory methods, are often unique.

This series of articles will be continued next month.
—Editor E.D.

U. S. A.

Powder Metallurgy Parts in High Temperature Applications

By J. J. HARWOOD (Deputy Head, Metallurgy Branch, Office of Naval Research). (From *Materials & Methods*, Vol. 36, No. 2, August 1952, pp. 87-91, 9 illustrations.)

Development and use of copper infiltrated iron, titanium alloy powders, sintered aluminium powder, molybdenum-base alloys and "cermets" are being hastened by shortages and service limitations of present high temperature alloys.

THE urgent need for conservation of our critical alloying elements such as cobalt, columbium and nickel has led to the development of leaner alloy composition for gas turbines now in production. The need for materials of superior high-temperature strength properties is being approached through the development of new refractory alloy systems, the development of metal-bonded refractory compounds commonly called "cermets" and the development of materials useful for artificial cooling techniques, e.g., permeable materials for sweat cooling. In all of these various developments, powder metallurgy methods and techniques are playing important roles.

JET COMPRESSOR PARTS.

An axial flow type jet engine requires 2000 to 3000 compressor blades. Since forged stainless steel was, until recently, the major compressor blading material, it is obvious that serious production and strategic material problems would be involved in the event of full-scale mobilisation.

Copper Alloy Infiltrated Iron—A major contribution to the alleviation of this problem has already been made by the development, by the American Electro Metal Corp., of copper alloy infiltrated iron stator blades which are now in production at the Thompson Products Corp.

This stator blade, known as TP-1, is made by moulding iron powder by means of a multiple action die into a preform shape. The preform is sintered and then coined to the exact dimensions of a compressor blade with the thin trailing edge and thicker leading edge. After coining, the porous blade is infiltrated with a copper alloy to 100 per cent density and heat treated to develop the required strength properties. Tensile strengths of 90,000 psi with elongations of 8 per cent have been reported.

The TP-1 blade is now being used as a standard compressor stator blade and is performing satisfactorily in service. It has been tested for use as a rotor blade material, for which the strength requirements are higher, and indications are that it may prove satisfactory for such applications also. Research is now under way to improve the high-temperature strength and impact properties of this material by appropriate alloying additions.

Titanium Alloys—These alloys are being used in limited production by Westinghouse Manufacturing Corp. as compressor disk materials to replace stainless steels. It is estimated that an appreciable weight saving will result from such a substitution. Titanium alloys are also being evaluated for use as compressor blade materials, and the indications are that they may be satisfactory for the first few compressor stages.

These applications are currently making use of wrought materials, but it is believed that powder metallurgy has much to offer in numerous contemplated applications for titanium and its alloys. One early disadvantage of pressed and sintered compacts was the relatively low endurance limit/tensile strength ratio. Compared to arc melted stock, which exhibited a ratio of 0·5 or higher, powder metallurgy samples displayed ratios of 0·3. This difference appears to be directly attributable to low density in the latter specimens. Methods have been developed for pressing titanium compacts to theoretical density, and recent tests have indicated that such compacts exhibit properties equivalent to those of arc melted material.

The Brush Development Co. has developed a method for the production of titanium powder from sponge material. No significant contamination is experienced in the powdering process. Compacts consolidated from such powder exhibit tensile strengths ranging from 65,000 to 85,000 psi with average elongations of 20 to

25 per cent. The strength and elongation properties are, of course, functions of the purity of the powder.

It seems reasonable that many applications exist for titanium alloys for which appropriate use of powder metallurgy processes can solve alloy and fabricating problems. For certain shapes, appreciable cost reduction can be an important consideration. The present price of titanium sponge is about $5·00 per lb. In the form of wrought products, e.g. sheet or plate, the price of titanium alloys jumps to $20 to $30 per lb. By resorting to direct pressing methods, and thereby omitting the cast ingot stage, it seems conceivable that this price could be reduced substantially. In addition, as is now the case with molybdenum and beryllium, titanium ingots of substantial sizes and weights should be able to be produced by powder metallurgy methods using hydrostatic pressing techniques. It must be noted that any high temperature operations with titanium, such as sintering, must be done under vacuum or inert atmospheres.

Sintered Aluminium Powder—An interesting Swiss development is that of a strong, high temperature aluminium "alloy" called SAP—Sintered Aluminium Powder. This new product shows potentialities for use at temperatures of 800° F, a 400° F increase over the best commercial high temperature aluminium alloy. SAP is produced by cold pressing aluminium powder of fine particle size into briquettes under a pressure of 20 to 50 kg/mm², sintering the briquettes at temperatures of 900 to 1100° F, followed by further hot pressing under 50 kg/mm², and finally extruding the material into rods. The density of the rods is 2·8 g/cm³. SAP rods can be further cold or hot worked into sheets, shapes or drop forgings.

The powder is produced by the Hametag process in an atmosphere low in oxygen. The shapes of the particles are flakes or lamellae with a particle size of 1—100 angstroms, with about 50 per cent of powder below 2 angstroms in one dimension. From the standpoint of metallic impurity, SAP is equivalent to commercial aluminium, but it contains between 10 and 20 per cent by weight of oxide. Presumably each particle is surrounded by a layer of aluminium oxide.

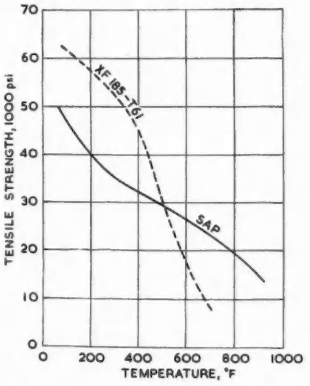

Fig. 1. High temperature tensile properties of sintered aluminium powder and aluminium alloys.

Exposure to temperatures as high as 900° F for as long as 100 hr results in little or no change in the room temperature tensile properties. Fig. 1 compares these properties with those of one of the best American high-temperature, age-hardenable aluminium alloys, RR58 (XF18S-T61). In general, it can be stated that the strength and creep resistance of SAP at 600° F are as much as 2 to 5 times greater than those of conventional aluminium alloys. In addition, the fatigue properties of SAP are generally superior to those of aluminium alloys at temperatures greater than 400 to 500° F.

Several industrial concerns are experimenting with SAP for component applications in standard engines, and in view of its high temperature strength properties consideration is also being given to its use as a compressor blade material. The making of finished shapes by direct hot pressing appears as a promising feature of this material.

TURBINE WHEELS.

Turbine wheels are composed of turbine disks and turbine blades. At present, the blades are either welded or mechanically fitted into the disk. Turbine blade materials must have high oxidation and erosion resistance, high creep and rupture strength over a range of temperature, high fatigue strength at operating temperatures, and resistance to thermal shock.

Three different approaches to the turbine blade materials problem offer considerable promise and are currently the subject of comprehensive research programs. These are the development of cermets (metal bonded refractory compounds); the development of transpiration cooled (sweat cooled) blades; and the development of molybdenum-base alloys. In all of these, powder metallurgy is playing an important role.

Cermets—In the field of cermets, metal-bonded carbides, borides, nitrides, aluminides, silicides and oxides are being investigated. These types of materials at the present time can only be fabricated into useful shapes by powder metallurgy methods. Procedures commonly used are conventional pressing and sintering operations, hot pressing, hydrostatic pressing methods, using oil and rubber bags, rubber moulding techniques to obtain uniform densities, or extrusion methods using a fugitive plasticiser.

One of the most promising cermets is the cemented titanium carbide compositions. These metal-bonded titanium carbides exhibit strength properties up to 1800 °F, and oxidation resistance and thermal shock characteristics which make them potentially useful turbine blade materials for present-day engines and which hold out a real hope for boosting turbine operating temperatures by several hundred degrees.

A variety of metal-bonded titanium carbide compositions has been developed by Kennametal, Inc. The most interesting grades at present employ a nickel binder and are being marketed as Kentanium K151A and K152B. K151A contains about 20 per cent nickel as a binder and some mixed solid solution carbides of tantalum and columbium. K152B also contains tantalum-columbium carbides and has a binder content of 30 per cent nickel. The addition of the mixed solid solution carbides enhances the oxidation resistance of titanium carbide which can satisfactorily resist oxidation at temperatures up to 2200° F.

The stress-rupture curves of titanium carbide compositions are shown in Fig. 2. Above 1500° F the high-temperature strength properties are comparable to or superior to those of many currently used alloys, even when density is not considered. Since the carbides have densities ranging from about 5 to 68 per cc, or 2/3 that of our present alloys, the centrifugal stresses developed would be proportionately lower.

On a strength/density basis, the high-temperature properties of titanium carbide compositions are superior to those of many alloys by a substantial factor. Recent work with non-strategic binder modifications indicate that the high temperature strength properties can be increased even further—possibly by as much as twice. Work in Europe also has led to the development of cemented titanium carbide compositions with equivalent high-temperature properties. The European grades contain chromium-nickel or chromium-cobalt materials in amounts up to 40 per cent. Trans-

verse rupture strength of these carbides at room temperature range between 175,000 and 225,000 and at 1800° F from 125,000 to 150,000. The 100-hr stress rupture life at 1800° F is 14,000 psi.

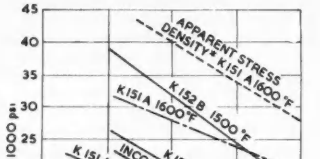

Fig. 2. **Stress-rupture properties of cemented titanium carbides. (Kennametal Inc.).**

$$\text{*Apparent stress density} = \frac{\text{stress K151A} \times \text{dens. Inconel X}}{\text{density K151A}}$$

(Applicable to rotating parts where centrifugal stresses at any one speed are proportional to density.)

Tests conducted by the National Advisory Committee for Aeronautics, the Navy and the Air Force revealed that titanium carbide compositions have satisfactorily withstood laboratory and simulated engine thermal shock tests by rapid quenching from temperatures as high as 2400° F. Fatigue tests, run at about 1400° F, indicate that metal-bonded titanium carbide has a ratio of fatigue strength to tensile strength of about ½. This compares favourably with many high temperature alloys at the same testing temperature. For 50×10^6 cycles, a fatigue strength of about 30,000 psi was found.

Titanium carbide turbine blades have run satisfactorily in engine tests for over 100 hr, although present blade designs are far from suitable for the use of brittle materials. New designs are being developed to overcome the lack of room-temperature ductility of the carbides and other cermet materials. The ultimate use of these non-ductile materials will depend upon design innovations that will avoid their deficiencies and make maximum utilisation of their strength properties. Since these materials are much stronger in compression than in tension, the use of compression loading would be a most beneficial design change.

Although research is continuing toward improving the properties of titanium carbides, 2200° F appears to be their upper temperature limit. To extend this temperature range, metal-bonded nitrides, borides, silicides and the like are also being investigated. Several compositions have been developed which show excellent high temperature strength at temperatures as high as 3000° F.

Materials for Sweat Cooling—A novel approach to the turbine blade materials problem involves the use of artificial cooling systems so that the blade is maintained at a temperature appreciably lower than that of the gas. One of the most efficient methods for accomplishing this objective is the use of transpiration, or sweat cooling, which consists of forcing a stream of coolant, either gas or liquid, through a porous body, in a direction opposite to the heat flow. The cooling medium gradually increases in temperature while passing through the porous body and finally reaches the inner wall surface, where it forms a protective layer.

The applicability of sweat cooling opens up new fields in powder metallurgy by extending the range of application of porous metals. With respect to turbine applications, sweat cooling offers two possible advantages. Less strategic alloy compositions can be used in present engines, since the blade temperature can be reduced to 1100° F or lower ; or the gas temperatures can be raised appreciably with continued utilisation of present turbine blade materials, which can operate at temperatures up to 1600° F.

The major problem involved is to develop porous alloys having maximum permeability and minimum porosity in order to obtain the high strengths required. Three general techniques are now being investigated for the preparation of controlled permeability bodies—loose powder sintering, cold pressing and sintering, and extrusion of metal powders using plasticisers or carriers. The latter technique has been developed to the point where rough blade shapes have already been prepared. Stainless steel powders are being employed in this initial work and bodies can be produced with permeabilities, in the desired range and with satisfactory strength values. A 500-hr stress rupture value of 20,000 psi can be obtained with an elongation of 3 to 6 per cent at time of failure.

Molybdenum-Base Alloys—Because of its high melting point, its known high temperature properties, and its availability in the U.S., molybdenum has been selected as the most promising of the refractory metals for super high temperature service. Powder metallurgy techniques have advanced to the stage where sintered and pressed molybdenum shapes measuring up to 6 in. sq., 4 ft long and weighing over 400 lb are not uncommon. Hydrostatic pressing techniques have made feasible the production of powder metallurgy ingots weighing up to 700 lb.

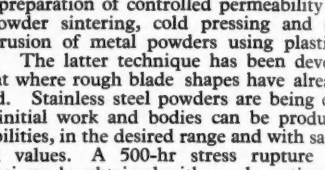

Fig. 3. **Stress-rupture properties of molybdenum and molybdenum alloys at 1800° F compared with other high-temperature materials.**

At temperatures above 1600° F, the creep and stress-rupture properties of commercially pure molybdenum are superior to those of any high-temperature alloy (Fig. 3). These high temperature properties vary considerably with the source of molybdenum powder, purity of powder, method of consolidation, fabrication, history and other factors. A recent comparison of the properties of arc cast and powder metallurgy specimens revealed equivalent properties when the metallurgical history and structure of the samples were equivalent.

In order to obtain superior high temperature strength properties, parallel research programmes are under way for the development of molybdenum-base alloys by both arc melting and powder metallurgy techniques. Alloys have already been developed which show outstanding stress rupture properties. The recrystallization temperatures of some of these alloys are about 1000° F higher than for commercially pure molybdenum.

Several obstacles still must be overcome before molybdenum alloys can receive widespread military application. Satisfactory protective coatings are needed to prevent the rapid oxidation which molybdenum and its alloys undergo. Certain brittle characteristics which cause welding, fabrication and service difficulties must also be overcome.

The Influence of Sound and Ultrasound on Electro-Chemical Processes

By A. ROLL. (From *Metalloberfläche*, Vol. 4, Nos. 4, 5 and 6, 1952, pp. B49-53, B65-70, and 81-89 respectively, 26 illustrations.)

(*Concluded from September issue*)

Fig. 13 gives the nickel yield against the current density, for different sound intensities. The temperature of the bath was 20° C. At lower current densities the yield is low, while at higher currents the hydrogen evolution is repressed by higher sound intensities.

Fig. 14 shows the deposition potentials. The maximum change caused by the ultrasound is of the order of 250 mV. From the measured hydrogen potential and the nickel yield it is possible to calculate the deposition potential of nickel, and this is shown in Fig. 15. Without sound, the potential rises very steeply even at low current densities. The potential increases with decreasing concentration; this means that the electrolyte is very rapidly impoverished in nickel ions. At about 4·5 mA/cm² a limit is reached when all the nickel ions at the cathode are discharged. At higher currents there is no increase in the numbers discharged, and hence the potential curve from this point runs practically horizontal.

Under the influence of ultrasound the potential rises more slowly as the intensity is increased. For intensities above 0·1 watt/cm², the limit at which there is a shortage of nickel ions is no longer reached at the current densities used. This suggests once again a stirring action of the sound, which supplies fresh ions to the boundary layer. Another possible interpretation is that the ultrasound increases the dissociation and, hence, the ion concentration in the electrolyte. However, conductance measurements indicate no change in the ion concentration.

The same experiments were repeated at a temperature of 50° C and with intensive stirring. Fig. 16 shows the number of nickel atoms deposited per cm² per sec as a function of current density for different external conditions. The close analogy between sound and stirring action is evident from the curves.

The stirring effect of the ultrasound may be explained by bearing in mind that some hydrogen is always evolved together with the nickel deposition. The velocity of the rising bubbles, which carry some liquid with them by friction, is increased by the radiation pressure of the sound. Thus, the electrolyte

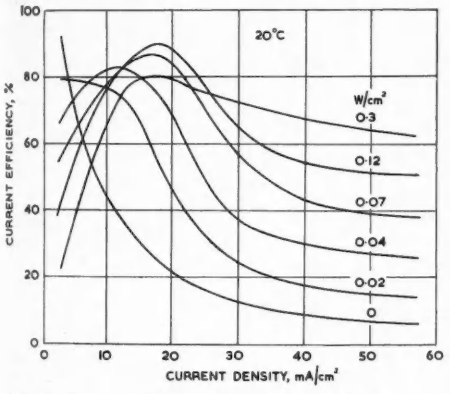

Fig. 13. **Current efficiency for various sound intensities.**

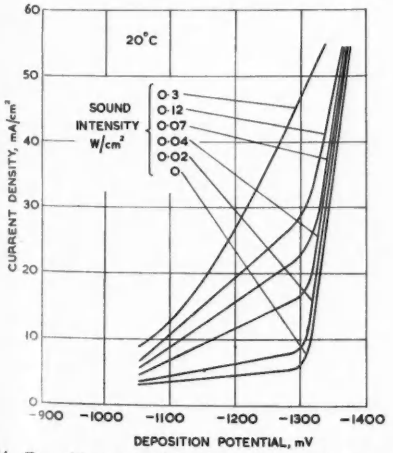

Fig. 14. **Deposition potential at various sound intensities.**

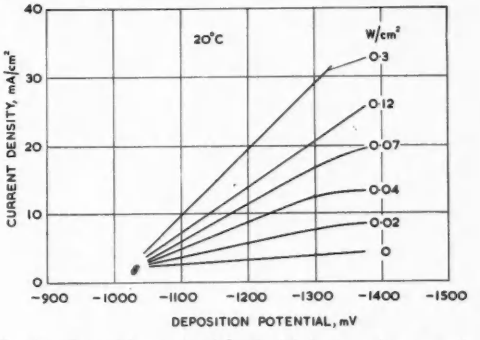

Fig. 15. **Deposition potential of nickel at various sound intensities.**

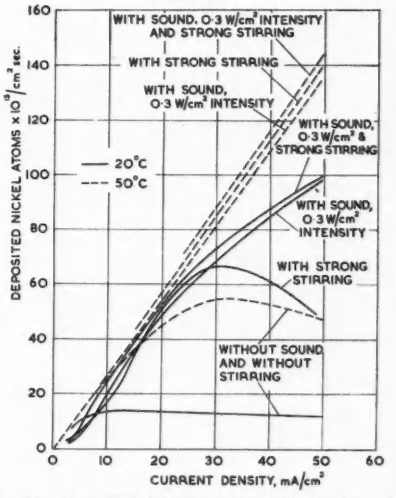
WITH SOUND, 0·3 W/cm² INTENSITY AND STRONG STIRRING
WITH STRONG STIRRING
WITH SOUND, 0·3 W/cm² INTENSITY
WITH SOUND, 0·3 W/cm² & STRONG STIRRING
20°C
50°C
WITH SOUND, 0·3 W/cm² INTENSITY
WITH STRONG STIRRING
WITHOUT SOUND AND WITHOUT STIRRING
DEPOSITED NICKEL ATOMS x 10¹³/cm² sec.
CURRENT DENSITY, mA/cm²

Fig. 16. **Number of nickel atoms deposited on 1 cm² per second.**

is agitated and the rate of equalising the concentrations in the boundary layers increased.

A similar change in the deposition potential and an increase in the yield was found for copper and silver, at current densities at which hydrogen was also evolved.

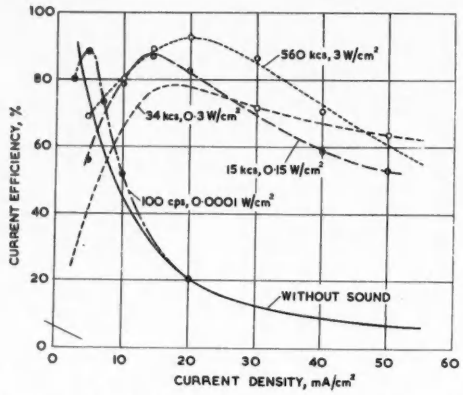

Fig. 17. **Nickel yield for various frequencies and intensities.**

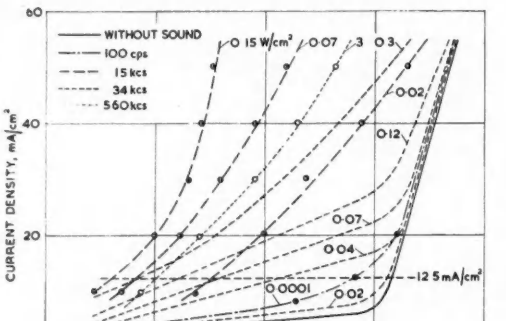

Fig. 18. **Cathode deposition potentials for various frequencies and intensities.**

As the stirring effect depends only on the sound intensity, the phenomena discussed above should be independent of the frequency. Experiments have been carried out at various frequencies to verify this.[13] Apart from the 34 kcs frequency, frequencies of 15 kcs, 560 kcs and 100cps were employed. The arrangement of the electrodes, the direction of sound and the electrolyte were the same as in the earlier experiments.

Figs. 17 and 18 give the results of these measurements. Fig. 17 shows the nickel yield for various frequencies and in each case the maximum available intensity. A simple interpretation of the effects of sound intensity and frequency does not appear to be possible.

In Fig. 18 the deposition potentials (on which the yield depends) are collated for various intensities and frequencies. The curves are very sensitive to outside influences, but less so at higher frequencies. From these graphs it must be concluded that the stirring effect of the ultrasound cannot depend on the frequency independent radiation pressure alone, and hence this explanation of the effect is insufficient.

The following quantitative consideration shows this even more clearly: assume that the stirring effect is proportional to the sound intensity I and inversely proportional to the frequency f. Then, for the same ratios I/f the same potential change should occur. On the further assumption that the change of potential ΔE is proportional to the "stirring factor" $R = I/f$, the relative change $\Delta E/R$ for the same current density should be constant for all experiments. Although this is a considerable oversimplification of the case, nevertheless, as Table I shows, this quantity is constant to within one order of magnitude. The values are taken from Fig. 18, for a current density of 12·5 mA/cm². The frequency-dependence of electrolytic processes is thus demonstrated. The lower the frequency, the more the electrochemical quantities are affected. This result contradicts the assumption that the frequency-independent radiation pressure is the cause of the electrochemical changes observed.

TABLE I. CALCULATION OF RELATIVE STIRRING EFFECT.

f cps	I w/cm²	ΔE mV	$R = I/f$	$\Delta E/R$
10^2	10^{-4}	30	10^{-6}	$3{\cdot}0\times10^{7}$
$1{\cdot}5\times10^{4}$	2×10^{-2}	160	$1{\cdot}3\times10^{-6}$	$12{\cdot}1\times10^{7}$
$1{\cdot}5\times10^{4}$	7×10^{-2}	225	$4{\cdot}7\times10^{-6}$	$4{\cdot}8\times10^{7}$
$1{\cdot}5\times10^{4}$	$1{\cdot}5\times10^{-1}$	250	$10{\cdot}0\times10^{-6}$	$2{\cdot}5\times10^{7}$
$3{\cdot}4\times10^{4}$	2×10^{-2}	5	$0{\cdot}6\times10^{-6}$	$0{\cdot}9\times10^{7}$
$3{\cdot}4\times10^{4}$	4×10^{-2}	90	$1{\cdot}2\times10^{-6}$	$7{\cdot}7\times10^{7}$
$3{\cdot}4\times10^{4}$	7×10^{-2}	160	$2{\cdot}1\times10^{-6}$	$7{\cdot}8\times10^{7}$
$3{\cdot}4\times10^{4}$	$1{\cdot}2\times10^{-1}$	195	$3{\cdot}5\times10^{-6}$	$5{\cdot}5\times10^{7}$
$3{\cdot}4\times10^{4}$	3×10^{-1}	225	$8{\cdot}8\times10^{-6}$	$2{\cdot}5\times10^{7}$
$5{\cdot}6\times10^{5}$	3×10^{0}	210	$5{\cdot}4\times10^{-6}$	$3{\cdot}9\times10^{7}$

W. T. Young and H. Kersten[14] found that metal deposited in the presence of standing ultrasonic waves has a rippled appearance. The metal is deposited preferentially at points of greatest radiation pressure. These are also points of vibration nodes where the amplitude of the oscillating particles is greatest. Thus, in the presence of standing waves the concentration of ions at the cathode is not uniform.

At higher frequencies, standing waves always occur. The higher the frequency, i.e., the shorter the wavelength in relation to the cathode dimensions, the smaller, on the average, is the stirring effect attributable to the radiation pressure. Qualitatively, therefore, the diminution of the stirring effect with increasing frequency is explicable. However, it will not be an easy matter to establish the exact frequency-dependence, because the widely varying conditions under which these frequencies are produced will introduce other, extraneous effects.

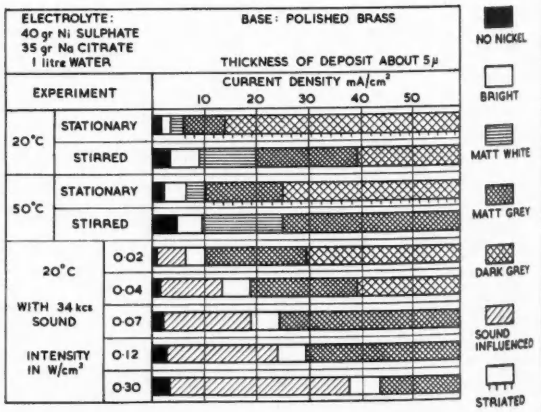

Fig. 19. **Types of nickel deposit obtained under various external conditions.**

From the experiments it appeared that the current densities at which a bright deposit was obtained were shifted towards higher values with the increase in sound intensity. For example, with a frequency of 34 kcs and 0·3 watt/cm² intensity, current densities of the order of 40 mA/cm² gave bright deposits, while in the absence of sound, 3 mA/cm² could not be exceeded. Fig. 19 gives a systematic picture of these investigations.[15] In addition to the known varieties of surface appearance of the deposit, a new type of surface, described as " sound-influenced," is observed at current densities below those which give a bright deposit. This surface is free of pores and shows no cavitation effects.

Plotting that part of the current density responsible for bright deposits (calculated from the total current density and the yield) against the sound intensity, we get a parabolic relationship, as shown in Fig. 20. It is noteworthy that the apex of the parabola lies in the region of negative sound intensity. An explanation of this will be given later.

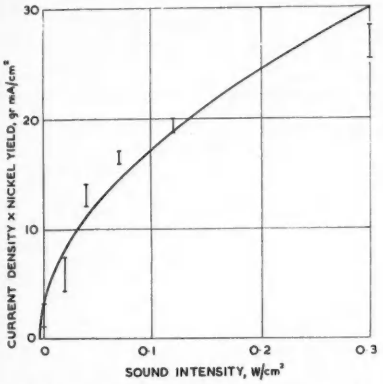

Fig. 20. **Relation between effective current and sound intensity.**

To interpret these results, it would be necessary to know the processes which lead to a bright deposit being formed. Unfortunately not much is known about these; a summary of available information is given in an article by J. Fischer.[16] According to this article, the effect of brightness, whether of cations or of colloids, is based on the fact that they do not fit into the crystal lattice. They are, however, preferentially deposited on the edges and corners of the lattice, thereby preventing further growth at these points. The newly arriving metal ions must therefore build a new nucleus of crystallisation, characterised by a higher polarisation potential, and favouring a fine granular structure which gives the bright appearance. When the brighteners are ineffective or missing, the deposit grows more rapidly at the corners and edges, causing a local impoverishment of ions, and the growth becomes coarse if the ions are not replaced quickly enough. If the rate of replacement is speeded up by an increase in temperature or concentration, or by the movement of the electrolyte (stirring), then dense, fine-grained deposits are again obtained.

Ultrasound can influence both factors responsible for giving bright deposits. The stirring effect has already been discussed. Experiments show, however, that stirring, in comparison with sound, shifts the bright region only slightly towards higher current densities. For the blocking of corners and edges through brightening agents, ultrasound can only be disadvantageous, preventing such action. The action of sound on the formation of bright deposits cannot, therefore, be understood from this point of view.

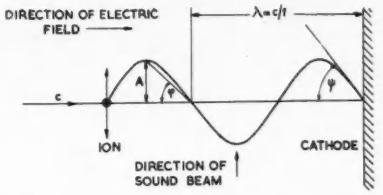

Fig. 21. **Motion of nickel ion during electrolysis in a sound field.**

In an ultrasound field, however, all particles experience an additional movement, oscillating with the frequency of the impressed wave. In an electrolyte the ions, therefore, perform the following movements: thermal vibrations, motion along the electric field, and oscillation in the ultrasound field.

Neglecting the thermal effect, the ion describes the following path (Fig. 21): the oscillating motion of amplitude A is superimposed on the uniform velocity c along the electric field. If the sound wave is sinusoidal, the ion will also describe a sine curve. Therefore, the ion will in general impinge at an angle φ on the cathode. This angle will depend on the relation between amplitude and path wavelength λ. We get $\tan\varphi = \dfrac{A}{\lambda/4} = \dfrac{4Af}{c}$; the amplitude is given by eq. (1) as $A = \dfrac{1}{\omega}\sqrt{\dfrac{2I}{\rho v}} = k_1\dfrac{\sqrt{I}}{f}$ and, therefore, the mean angle of impact $\tan\varphi = k_2\dfrac{\sqrt{I}}{c}$ is proportional to the square root of the intensity and inversely proportional to the drift velocity c. It may be assumed that the stirring action of the ultrasound keeps the ion-concentration in the boundary layer uniform and equal to the average concentration. Then the drift velocity is proportional to the effective part of the current density $g = s \times p$ (s = current density, p = current efficiency). Then

$$\tan\varphi = K\frac{\sqrt{I}}{g} \text{ and } g^2 = \left(\frac{K}{\tan\varphi}\right)^2 I$$

The relation between effective current and sound intensity is again parabolic, if the mean angle of impact φ is taken as constant in the region of bright deposit.

The results described above may now be explained under the assumption that bright deposits are always obtained when the ions during deposition arrive at a certain mean angle to the cathode. How far such an angle can be ascribed to the complicated process of discharge at the cathode is questionable. No observations, however, contradict this assumption.

The thermal motion of the ions has so far been neglected in the discussion. This motion is distributed randomly about the direction of drift, also causing the ions to impinge at an inclined direction to the vertical. The heat motion is responsible for the anomaly observed in Fig. 20, i.e., that the apex of the parabola does not pass through zero. Zero current density corresponds to a sound intensity of 0·003 watt/cm², which, in its effect on the angle of impact, just cancels the thermal motion at 20° C.

The action of brighteners, usually organic substances, has been discussed above. However, such additions probably also alter the hydration of the ions, hence altering both their drift and thermal velocities. As the angle of impact depends on these velocities, it is possible that the action of brightness also depends on

bringing about an angle of impact at which bright deposits are formed.

Mechanical stirring also has the effect of increasing the angle of impact by speeding up the ions. To bring the angle back to its required value, the drift velocity must also increase, i.e., higher currents are necessary.

For the bright surfaces, formed under ultrasound influence before the actual bright region is reached, the angle of impact must, according to the above considerations, be too large. According to the calculations, the angle of impact depends only on the intensity, not on the frequency. Tests at 15 kcs and 560 kcs support this conclusion.

It is impossible to distinguish the bright deposits obtained under ultrasound influence from those formed under ordinary conditions at lower current densities, and even X-ray measurements fail to reveal any difference. Thus, ultrasound so alters the factors responsible for a certain form of deposit that the same form is obtained at higher current densities. However, this can only be said of deposits formed when the direction of sound is parallel to the cathode surface.

Experiments on deposition in the presence of high-intensity ultrasound resulted in deposits strongly attacked by cavitation. The current efficiency was also less than that in the absence of sound, contrary to that found when less intense beams were used. This may be explained by the dispersive effect on the particles by the intense sound.

The crystalline structure of an electrolytically deposited metal depends, apart from the properties of the metal, to a great extent on the electrolyte and the conditions of electrolysis. A summary of practical rules about the conditions under which columnar, twin or other forms of crystals are formed, can be found in an article by W. Pfanhauser.[17]

It has been shown in various experiments on silver, nickel and copper, that the effect of ultrasound is to coarsen the grain of the deposit, and it also favours twinning. Stirring has a similar effect.

Summary: Intensive ultrasound can improve the mechanical qualities of an electrolytic deposit, but can also disperse the deposit into the electrolyte again, and be used to produce metallic emulsions and colloidal solutions. Low intensity ultrasound has a stirring effect, increasing the yield and reducing the deposition potential. This effect appears to be independent of intensity and frequency. Ultrasound also increases the current density at which bright deposits are formed. This is attributed to an alteration of the mean angle of impact of ions on the cathode. Stirring and ultrasound have a similar effect on the formation of the crystal structure of the deposit.

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U. S. A.

Brazing Hydromechanics

By E. R. Funk and H. Udin. (From *The Welding Journal*, Vol. 31, No. 6, June 1952, pp. 310s-316s, 9 illustrations.)

The factors affecting the rate of completion of a brazed joint are studied by the application of the elementary laws of hydrodynamics. A relation is found between the physical constants of the brazed metal, the joint dimensions and the interface velocity of both horizontal and vertical joints. The flow through two types of capillary dams is considered. A modification is introduced for the case of fluxed joints. The implications of the results for designs for brazing are discussed.

Introduction.

Brazing differs from welding in that filler materials having a melting point below that of the base metal are used for making a joint without melting the parent metal. In all true brazing operations, the liquid filler metal spreads until the volume between the parts to be joined is filled. In this paper the factors affecting the rate of completion of the brazed joint are studied. In its simplest form, the brazing operation is analogous to water moving through a duct, since it consists of a liquid moving between two flat solid surfaces.

The horizontal brazed joint.

A cross-section of a horizontal lap joint being brazed is shown in Fig. 1. An enlarged view of the advancing front of the brazing compound is presented in Fig. 2. The curvature of the front is due to surface tension, which produces the pressure driving the brazing liquid between the plates. This pressure is related to the surface tension by

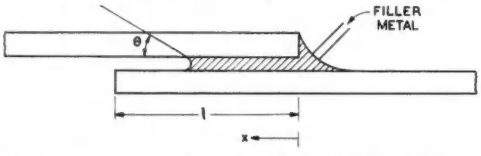


Fig. 1. **The cross-section of a horizontal brazed joint.**

$$\Delta P = -\frac{2\gamma \cos\theta}{D} \quad .. \quad .. \quad .. \quad (1)$$

where γ is the surface tension of the filler alloy, and θ is the angle of contact.

For perfect wetting, as in Fig. 2, $\cos\theta = 1$, and the pressure across the surface reduces to

$$\Delta P = -\frac{2\gamma}{D} \quad .. \quad .. \quad (2)$$

Under conditions of brazing it may be assumed that laminar flow of the alloy occurs. For this case, the velocity v at any point y between the surfaces is (see Fig. 2)

$$v = \frac{1}{2\mu}\left(\frac{dp}{dx}\right)(y^2 - yD) \quad .. \quad .. \quad (3)$$

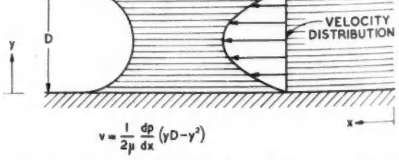


Fig. 2. **The velocity distribution in laminar flow.**

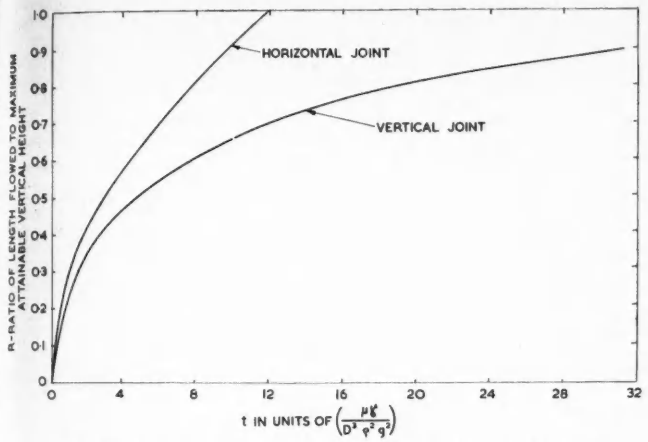


Fig. 3. **Comparison of time to fill horizontal and vertical joints.**

where μ is the viscosity and D is the distance between flats. The average velocity $\bar{v}$ can then be shown to be

$$\bar{v} = -\frac{1}{12\mu}\left(\frac{dp}{dx}\right) D^2 \quad .. \quad (4)$$

For a uniform spacing (dp/dx) is actually $\Delta P/x$; substituting this and eq. (2) into eq. (4), the time t for flowing a distance x can be found by simple integration. Re-writing this latter expression, we get for the distance flowed in time t :

$$x = \sqrt{\frac{\gamma D}{3\mu}}\, t \quad .. \quad .. \quad (5)$$

From the form of eq. (5) it is evident that a high γ/μ ratio is desirable for brazing compounds. The possibilities for decreasing the γ/μ ratio lie primarily with decreasing the viscosity. Increasing the surface tension above the highest value possessed by any element in the brazing alloy appears to be thermodynamically impossible. Nevertheless, contrary to most statements in the brazing literature, the highest surface tension compatible with complete or nearly complete wetting is always to be desired.

The surface tension γ is practically independent of the temperature, while the viscosity μ decreases exponentially with temperature, thus leading to a ratio γ/μ increasing with temperature.

The vertical brazed joint.

While there is no theoretical limit to the distance the brazing alloy may flow between horizontal flats, in vertical brazed joints a limit is set to the height of the liquid column by the weight of the column. The maximum height y_{max} to which the column can rise is, by elementary theory,

$$y_{max} = \frac{2\gamma}{\rho g D} \quad .. \quad .. \quad (6)$$

where ρ = density of brazing liquid (the density of the surrounding medium, normally gaseous, is neglected), g = acceleration due to gravity.

A calculation similar to the horizontal case gives for the time-distance relationship

$$t = \frac{12\mu\gamma}{\rho^2 g^2 D^3}\left[-2R - 2\log_e(1-R)\right] \quad .. \quad (7)$$

where $R = y/y_{max}$.

Comparison of vertical and horizontal brazed joints.

Since many joints are brazed in the vertical position, it is of interest to see what advantage might be gained by brazing these joints in the horizontal position. Fig. 3 shows a comparison between times taken to fill a joint in the horizontal and the vertical position, distances being specified in terms of y_{max}. It is apparent that, as long as the joint length is not too close to y_{max}, the time for filling a vertical joint is not appreciably longer than for a horizontal joint.

It will be useful to have some idea about the magnitude of y_{max} in a hypothetical joint using pure copper on iron. For such a case γ = 1100 dynes/cm, ρ = 8·94 g/cm³. Taking D = 0·005 in., we obtain from eq. (6) y_{max} = 1·95 cm = $\frac{3}{4}$ in.

We can see from Fig. 3 that a $\frac{1}{2}$-in. joint would be completed about 50 per cent faster in the horizontal position than in the vertical position. A smaller joint thickness will lead to much less time-saving, and it is clear that the advantages of vertical brazing in minimising the air entrapment far outweigh the time saving in horizontal brazing. Working out the time required to complete a $\frac{1}{2}$-in. lap joint of 0·005 in. thickness, from eq. (5), we get t = 1·1 seconds.

Under actual brazing conditions a flux is always present. In this case the plate as well as the brazing compound are in chemical equilibrium with the flux. The mathematics of this more realistic case are unchanged but the values of μ and γ for the brazing compounds are affected. γ becomes here the interfacial tension between the liquid metal saturated with flux and the flux itself. This makes it desirable for the surface tension of the flux to be low. However, a minimum value for the surface tension of the liquid flux is not necessarily the condition for maximum interfacial tension.

Impeded flow—Capillary dams.

In actual practice the plates to be brazed are seldom perfectly flat, as tool marks or peculiarities of joint design obstruct the free flow of the brazing liquid. Obstructions caused by a change in cross-section of the capillary tube may be called capillary dams. These can be of two types, one in which the cross-section becomes larger for a short distance, and the other in which the cross-section becomes constricted.

Schematic examples of the two types of capillary dams are considered. Fig. 4 is a dam in which the cross-section expands uniformly from D to $(n + 1)D$. As the dam begins to fill, the pressure driving the liquid decreases as the radius of curvature increases, in accordance with eq. (2). In addition, more liquid is required to fill the dam. Both these conditions slow down the rate of flow in the dilated portion.

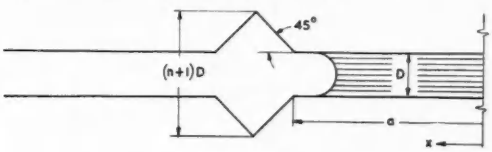


Fig. 4. **A dilated capillary dam.**

The result of a somewhat cumbersome analysis is that the time t to fill past a dam which is a distance a from the beginning of the joint and size $(n + 1)\ D$ is given by :

$$t = \frac{6\,\mu\,a\,n}{\gamma}\left(1 + \frac{n}{2}\right) + \frac{3\,\mu\,a^2}{\gamma\,D} \quad .. \quad (8)$$

The viscous drag within the groove has been neglected in the derivation. If this drag is included, the resulting equation is unwieldy, but upon evaluation it is not appreciably different from eq. (8) as long as a is large compared to D.

Let the dam be simply a groove of depth D on each face, so that $n = 2$. If this dam is $\frac{1}{4}$ in. from the edge, and the joint is 0·005 in. thick, then it will take about thirty times as long to fill past the dam as it would it no dam were encountered.

If a dam of this nature occurred in a vertical joint, there is the likelihood that it would completely stop the upward flow. It can be seen from eq. (6) that the maximum obtainable height is inversely proportional to the radius of curvature. This means that as n increases, the maximum obtainable height decreases. An advancing front will be permanently stopped when the groove occurs between y_{max} and $y_{max}/(n + 1)$.

The other kind of dam is a constriction in the capillary, shown in an idealized form in Fig. 5. Although the radius of curvature decreases in this dam, resulting in rapid movement through it, the flow of the liquid past it is cut down. It is common practice to express the flow-retarding characteristics of an orifice in terms of the number of diameters the orifice effectively adds to the length of the system beyond the orifice. Using this convention, it can be shown that the effective increase in length is $(m^2 - 1)\ D/2$. m is a measure of the constriction as shown in Fig. 5. In order to affect the speed of brazing noticeably, m must become quite large.

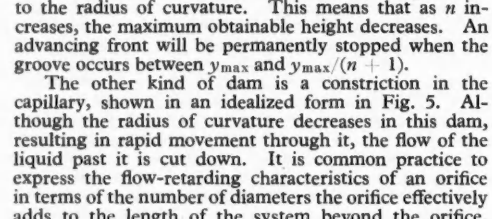


Fig. 5. **A constricted capillary dam.**

If the constricting dam occurred in a vertical joint, the maximum obtainable height would not be affected, while the time required would vary the same way as for the horizontal joint, that is, very little retarding until the gap becomes much smaller than the joint dimension.

THE EFFECT OF A FLUX.

In practice it is difficult to achieve a satisfactory brazed connection without the use of a flux. A flux is a chemical agent, generally a metal halide or borate, which aids the brazing operation by dissolving the oxides which have formed on the metal surfaces. It also coats the cleaned surface to prevent further oxidation.

The influence of a flux on brazing can be examined analytically. Taking the simplest case of the horizontal joint (Fig. 6), the brazing alloy must displace the flux by pushing it out of the joint. In this case the driving force has to overcome the flow resistance of the flux as well as that of the liquid metal. Analysis gives for the time t to fill to any point :

$$t = -\frac{6\,x^2}{D^2\,\Delta P}(\mu_m - \mu_f) - \frac{12\,\mu_f\,l\,x}{D^2\,\Delta P} \quad .. \quad (9)$$

where $\Delta P = -2\,\gamma_i/D$

γ_i is the interfacial tension between flux and metal. This quantity has to be established experimentally, and cannot simply be equated to the difference between γ_m and γ_f.

The effect of the flux under various conditions can be seen by examining eq. (9) for three cases.

(1) When μ_f is very small compared with μ_m. Then

$$t = \frac{3\,x^2\,\mu_m}{2\,D\,\gamma_i} \quad .. \quad .. \quad .. \quad (10)$$

This result is very similar to the result in the previous section in which the flux was neglected.

(2) When μ_f is much larger than μ_m. Then

$$t = \frac{6\,\mu_f}{D\,\gamma_i}\left[x\left(l - \frac{x}{2}\right)\right] \quad .. \quad (11)$$

In this case the velocity is slow and characteristic of the flux at the beginning of the filling, but increases as the joint is completed.

(3) When μ_f and μ_m are approximately equal, the time simply becomes

$$t = \frac{6\,\mu_f\,l}{D\,\gamma_i}\,x \quad .. \quad .. \quad .. \quad (12)$$

The rate of movement of the interface for this case is constant.

The conclusions reached here may be applied to vertical joints, remembering that the maximum attainable height is influenced by the density of the flux.

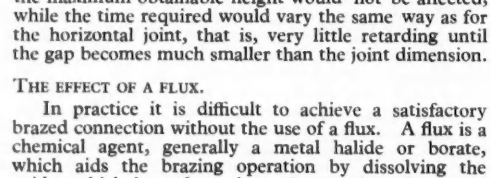


Fig. 6. **A slag-metal interface in a horizontal joint.**

CONCLUSIONS.

In the design of brazed joints, attention to clearance is necessary. An abrupt change in clearance leads to capillary dams which impede the flow of the brazing compounds. Two examples of bad joint design should be mentioned : (1) a rounded washer on a right-angle tee, where the wide clearance at the fillet will slow down, or possibly completely stop, the flow of the brazing compound into the joint ; and (2) a square cross-section washer on a rounded angle, which will limit the flow of brazing liquid. Two general rules may be stated for design : (a) keep joint clearance uniform throughout and (b) avoid line contacts of the parts to be joined.

For short joints, the time for filling a vertical joint is only slightly longer than the time for completing a horizontal joint of the same length.

Surface preparation is important in brazing. A poor surface finish will hinder or completely stop the filling due to the presence of many capillary dams of varying characteristics. The finer the finish, the less the impedance to flow. Surface scratches or tool marks are far less detrimental if they run in the direction of the metal flow rather than perpendicular to it. In fact, if the angle of contact between base and filler metals is greater than zero, fine scratches in the direction of the joint will actually speed the filling.

In the consideration of the brazing alloy and flux, it was seen that an alloy of high surface tension or high flux-metal interfacial tension is desirable, consistent with the surface energy requirements of wetting. More rapid filling is obtained when both the slag and the molten metal have low viscosities.

CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns, are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

ELECTRIC MOTORS AND GENERATORS

The Problem of Motor Protection

By R. SINAVE. (From *ACEC Charleroi*, Belgium, No. 1, 1952, pp. 2-29, 34 illustrations.)

CIRCUIT-BREAKERS and contactor-circuit-breakers with therme-magnetic protection make it possible to obtain reliable and complete protection of motors, provided that their maximum rupturing capacity is compatible with that which is appropriate, at their place of installation, to the short-circuit power of the network on the supply side.

If their rupturing capacity is inadequate, it is only necessary to connect on the supply side, either an appropriate circuit-breaker with electromagnetic protection or high rupturing capacity fuses.

Protection by thermal relay and fuse can be used provided that the rated current of the protective fuse on the supply side is suitably reduced. In this case, more frequent fusing is probable, and it is not advisable to use this form of protection except for low-powered motors.

The time constant of thermal relays should have a value well below that of the motor when running. This rule makes for effective protection of the machine and avoids over-lengthy waiting periods before re-closing resulting in prolonged interruption in operation.

Individual protection is preferably left to thermo-magnetic circuit-breakers with a high rupturing capacity. Group protection can, in most cases, be usefully carried out by fuses or by high rupturing capacity circuit-breakers.

Working conditions very often entail doing without general protection on the low voltage side and the substitution of general protection on the high voltage side.

Where general protection is retained on the low voltage side, it should preferably be left to high rupturing capacity circuit-breakers.

POWER PLANT ENGINEERING

Metal Temperature in Regenerative and Recuperative Air Preheaters

By T. A. WIDELL and S. I. JUHASZ. (From *Acta Polytechnica, Sweden*, Mechanical Engineering Series, Vol. 2, No. 6, 48 pages, 29 illustrations.)

AIR preheater troubles are direct or indirect consequences of condensation from the flue gas on the metal surface. The difficulties have increased in recent years due to increased efficiency and to the fact that inferior fuels are widely being used. The increase of surface temperature is no end in itself but, on the contrary, a necessary disadvantage.

Different methods used to increase the surface temperature are described. It is shown how the different factors which determine the surface temperature are influenced by these methods. By taking the "cold air" from the hottest point of the boiler-house, with hot air recirculation, with separate preheating of the air, and with flue gas recirculation, the temperature of the incoming cold medium is increased. With cold air by-pass, by-passing the flue gas at the economiser, or by decreasing the air preheater surface, the temperature of the exit flue gas is increased. The methods mentioned also result in secondary effects which may either be favourable or unfavourable from the point of view of wall temperature.

By changing from counterflow to parallel flow, the surface-temperature at the cold end is increased, but to an unnecessarily high value, which must be paid for by increased flue gas losses and decreased hot air temperature, both causing an increase in fuel consumption.

A new method is suggested for regenerative rotary air preheaters; a combination of counterflow and parallel flow, which gives the possibility of increasing the metal temperature at the cold end to the required degree, thus avoiding unnecessarily high flue gas losses and too low a hot air temperature. By this system, "combiflow," the rotary air preheater is divided into three sections, i.e., for the flue gas, counterflow and parallel flow air.

The hot air recirculation, the change from counterflow to parallel flow, cold air by-pass and decreased surface area have been computed generally by means of the dimensionless air side temperature efficiency, which is independent of the individual temperatures. In the computation of hot air recirculation and cold air by-passing, the terms "small and large balance circuit" are used. The computation is based on the principle that the air side temperature efficiency depends only upon the mass flow in the small balance circuit. Furthermore, the ratio of water equivalents is constant in the large balance circuit. Parallel flow and decreased surface (where no small and large circuits, but only one circuit, exist) are calculated.

Differential equations have been set up for "combiflow." The solution of the homogeneous differential equation system of the first degree yields three functions, each consisting of the sum of 3 exponential terms. It can be seen that all temperatures with "combiflow" are between the values which hold for pure counterflow and pure parallel flow.

It can be said that with a small increase of surface temperature (30° C), hot air recirculation is the cheapest in operation, but a separate or larger air fan must be used. This auxiliary fan can be as large as the ordinary fan. With greater increases of wall temperature, "combiflow" is cheap both in operation and in first cost. The first cost of pure parallel flow is the cheapest, but the operating cost is very high. Cold air by-pass and decreased surface area can be used at plants where corrective measures must be taken afterwards. These methods are cheap in first cost but the most expensive in operation.

Automatic control can be used with some of the methods mentioned above to bring about an increase of the surface temperature to an optimum value.

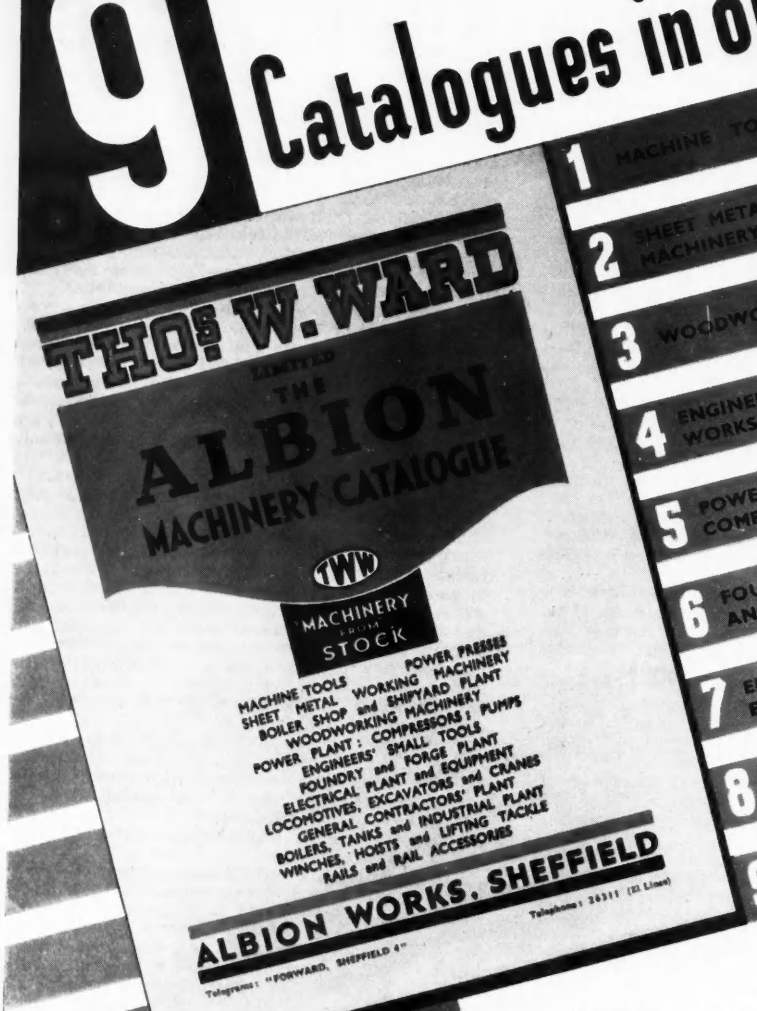
WASTE ELIMINATION

Alnico Recovery Process for Salvaging Nickel and Cobalt

By A. H. SHERMAN and M. PESSES. (From *The Iron Age, U.S.A.*, Vol. 170, No. 1, July 3, 1952, pp. 115-119, 6 illustrations.)

AN economical metallurgical method for the recovery of nickel, cobalt and copper from the discarded grindings and skimmings resulting from permanent-magnet manufacture has been developed by the Alter Company, of Davenport, Iowa.

9 Catalogues in one.....



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As no other industries can absorb the complex alloy wastes, apart from the ceramic colouring industry which uses only a very small proportion, it was considered that the best solution would be to refine the waste drosses and residues for re-use by the permanent magnet industry. The process has passed through the pilot plant stage and full-scale production should soon be under way.

The wastes consist of Alnico skimmings and by-products of grinding. The skimmings are metal particles in a highly refractory alumina slag, and the grindings are mixed with abrasives and oil or water. About 20 per cent of the magnet materials is normally lost in slags and grindings during manufacture, and the new process gives the possibility of recovering approximately 3 per cent of nickel, 5 per cent of cobalt, 9·8 per cent of iron and 0·6 per cent of copper. Only the aluminium is unreclaimable.

The experimental work required the design of suitable furnaces and processing machinery for the preparation of the material for smelting and refining. The crucible furnaces initially developed had a hot-metal capacity of 500 lb and used twin oil burners tangentially fired into the furnace with a high-pressure jet nozzle. The final models are rotary reverberatory non-crucible oil-fired furnaces with a 4000 lb capacity, which are fully satisfactory, whereas difficulties had been previously experienced with tilting-type reverberatory non-crucible furnaces. The furnace in the pilot plant permits the tapping of heats of 3000-4000 lb, and the full-scale production plant will have two high-frequency furnaces.

The three types of dross are first treated separately. The skimmings are crushed, while the wet grindings with oil or water are cleaned in a detergent before drying. The materials are sorted in a double-belt magnetic separator with variable field strength, and then reblended.

In the blender, a certain proportion of aluminium is added to the skimmings as a deoxidising agent and to comply with alloy specifications. Iron oxide is added as an oxidising agent and to eliminate excess carbon. Silica and sodium silicate are also added, in proportions which depend on the amount of aluminium oxide in the skimmings or produced by oxidation of the aluminium added. This gives a marketable slag with a composition similar to that of albite, a mineral which is used as a flux and colorant in the ceramic industry.

After blending, the material is charged into the furnace and heated to a maximum temperature of 3000-3300° F. The first aluminium addition is made after heating for six hours in the furnace, and forms an alumino-thermic reaction which reduces the oxides of nickel, cobalt and iron in the melt. Further aluminium is then added to meet the specifications. Just before pouring, sufficient iron oxide is added to lower the carbon and silicon content of the bath, which is poured out as shot or ingot and supplied to magnet manufacturers for final remelting.

This process recovers materials at only one-third of the cost of the virgin metals, and makes possible the reprocessing of millions of pounds of valuable metals which can be returned to industry.

OLYMPIA AND HANOVER

(*Concluded from page* 337)

Was there any progress in general ?

Without asking Dr. Joad's opinion as to what he, and we ourselves, are to understand by progress, we would say that real progress is simplification. Looking down on the National Hall from The Engineers' Digest stand we could see a peculiar looking machine with a great number of moving parts. This was the Essex punch shaper, built along the lines of a German machine which first came on the market more than 20 years ago. Not far from this Stand we could study the Nassovia punch shaper performing a similar operation and based on similar principles, but considerably improved and incorporating a planetary gear for the swinging movements. From the outside we could see practically no moving parts. Again, on the same floor, we could see the small Gack punch shaper, a small neat horizontal machine, in which the tool performs exactly the same swinging movement at the end of the cut as in the two machines previously mentioned. Is this the end of the development ?

Is geometric production or copying the principle of the future ?

Our principal machine tools are based on geometric production or generation, the tool in the lathe generating a cylinder or screw threads, the shaper and planer plane surfaces, etc., but whilst these machines produce geometrically correct surfaces, their limitations soon become apparent. In modern engineering, it is not always possible to use simple geometric surfaces, but complicated shapes, profiles and all kinds of surfaces have to be used. Whilst such surfaces were formerly produced by moving slides and tables in the required geometric path or were even produced by hand, these methods are now considered obsolete. Many modern machine tools can reproduce any shape which is at first formed into a master or template. Here again we have a revolution in detail, and while originally only used on lathes and special milling machines, the idea is now extended to shaping machines, grinding wheels, etc., which leads to interesting new problems, such as the profiling of grinding wheels by several methods. A number of them using pantographs and slides were shown for the first time at any machine tool exhibition. Whilst special machines may incorporate these principles, much attention is today given to devices which can extend the possibilities of existing basic machines.

PROPERTIES OF SOME HIGH TITANIA DIELECTRIC CERAMICS

(*Concluded from page* 342)

reduce the particle size, the milling is only continued until this result is secured. The milling is followed by drying and pulverising before proceeding with the previously outlined steps for body preparation. In reference to wet milling, it should be repeated that care beyond normal ceramic needs is required to produce satisfactory electrical properties.

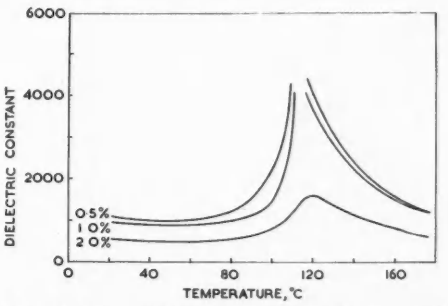

Fig. 6. **Variation of dielectric constant with temperature for $BaTiO_3$ containing 0·5, 1·0, or 2·0 per cent silica.**

This can be illustrated by Fig. 6 which shows the effect produced by increasing silica upon the dielectric constant of barium titanate at different temperatures. It is seen that at all temperatures, this constant has been reduced by silica above 0·5 per cent, and at the Curie temperature the effect is particularly noticeable. Since silica is a contaminant which can be picked up in the milling process, it is evident that attention must be paid to using the proper amounts of water, grinding media, charge and milling time, to avoid any appreciable erosion of the mill lining or balls.

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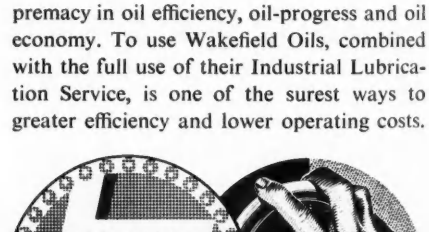

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NEWS OF THE MONTH

PERSONAL

Mr. A. St. H. Aubrey, blast-furnace manager of the Skinningrove Iron Co. Ltd., Saltburn-by-the-Sea, Yorkshire, has been appointed works manager of the Sheepbridge Coal and Iron Co. Ltd., Chesterfield.

Mr. Harry Bull, managing director of Brown Bayley Steels Ltd., Attercliffe, Sheffield 9, and chairman of Welding Rods Ltd., Sheffield, has been appointed a member of the Regional Board of Industry.

Mr. G. A. T. Burdett has joined Holophane Ltd., Elverton Street, London, S.W.1, as publicity manager, in succession to **Mr. R. J. W. Briddon,** who now represents the Company in the South-Western area.

Mr. G. E. Chicken and **Mr. C. Hipwell** have been elected directors of Dorman Long & Co. Ltd., Middlesbrough. **Mr. S. Barlow, Mr. James Jack** and **Mr. J. H. Patchett** have been appointed special directors of the Company.

Mr. H. J. C. Earp, A.I.E.E. has been appointed Midland Branch manager, and **Mr. W. R. Hastings, A.M.I.E.E.,** assistant sales manager, of Contactor Switchgear Ltd., Moorfield Road, Wolverhampton.

Mr. K. M. Fox, A.M.I.E.E., has been appointed manager of the British Thomson-Houston Company's district office at Swansea, in succession to Mr. S. J. Clarke, who will be taking up another appointment in the B.T.H. organization.

Mr. E. V. Hainsworth, chairman and managing director of Edward Elwell Ltd., Wednesbury, has been appointed deputy chairman of Edge Tool Industries Ltd., Wolverhampton.

Mr. J. R. Y. Johnston, M.I.N.A., has been appointed naval architect to the Canadian Pacific Steamships Ltd., with headquarters in Liverpool.

Mr. J. H. Kirby has been appointed shipyard manager of Smith's Dock Co. Ltd., North Shields, in succession to **Mr. T. E. Shaw** who has retired after 37 years service with the Company.

Mr. K. G. Leach, M.A.(Cantab.), A.M.Inst.C.E., A.M.I.E.E., has been appointed manager of the British Thomson-Houston Company's sub-office at 25 Baldwin Street, Bristol.

Mr. T. W. Mills has been appointed manager of the Stella Gill Coke and By-product Works, Pelton Fell, Chester-le-Street, Co. Durham. **Mr. R. Chambers** has been appointed under-manager at Derwenthaugh Coke Works, Blaydon-on-Tyne.

Mr. Henry Nimmo, M.Inst.C.E., M.I.Mech.E., M.I.E.E., has been elected President of the Engineers' Guild, Abbey House, 2 Victoria Street, London, S.W.1, in succession to **Mr. Robert Chalmers, O.B.E., B.Sc., M.Inst.C.E., M.I.Mech.E.** Mr. Nimmo is chairman of the Southern Electricity Board and part-time member of the British Electricity Authority. He is also chairman of the Electrical Development Association.

Dr. B. J. O'Kane, A.M.I.E.E., has been appointed chief air radio engineer, **Mr. R. R. Stanford-Tuck,** sales manager, and **Mr. F. Wheeler,** contracts manager of the aeronautical division of Marconi's Wireless Telegraph Co. Ltd., Chelmsford.

Mr. Edward Player, managing director of Birmid Industries Ltd., Smethwick, Birmingham, has been appointed chairman of the Aluminium Industries Council, in succession to **Mr. H. E. Jackson,** Metals Division of Imperial Chemical Industries Ltd.

Mr. C. E. Prosser has been appointed deputy chairman, and **Mr. M. J. S. Clapham** has succeeded Mr. Prosser as joint managing director of the Metals Division of Imperial Chemical Industries Ltd.

Mr. J. T. Rymer has resigned from his position as managing director of Mirrlees, Bickerton and Day Ltd., Stockport. **Mr. C. F. Barnard,** assistant managing director, has been appointed general manager of the Company. He will remain a member of the Mirrlees Board and be responsible for the future management of the firm.

Mr. G. T. H. Spurling, B.Sc., A.M.I.Mech.E., has resigned his position as commercial manager of the turbine division of the Brush Electrical Engineering Co. Ltd., on his appointment as chief assistant to **Mr. I. V. Robinson, Wh.Sc., M.I.C.E., M.I.Mech.E.,** head of the turbine and allied plant sections of the British Electrical and Allied Manufacturers' Association, 36/38 Kingsway, London, W.C.2. **Mr. B. L. Gover** has been appointed commercial manager of the turbine division of the Brush company.

Mr. R. H. S. Turner, M.A., M.I.P.E., has been appointed assistant works manager, Main Works, Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester 17. **Mr. A. Paterson, B.Sc., A.R.T.C., A.M.I.P.E.,** in addition to his duties as superintendent of the motor department, has been appointed assistant works manager, Mosley Road Works, including Leonard Works, **Mr J. S. Wright, B.Sc. (Eng.), A.M.I.E.E.,** has been appointed superintendent of the plant department, and **Mr. J. A. Brooks, B.Sc.(Eng.), A.M.Inst.W.,** superintendent of the Leonard Works. **Mr. R. M. A. Smith, B.Sc.(Eng.), M.I.E.E.,** is now assistant sales manager of the instrument and meter department.

Sir Harold West, managing director of Newton Chambers & Co. Ltd., one of Britain's leading industrialists, has been installed as the 315th Master Cutler, head of the ancient Company of Cutlers in Hallamshire, and so virtually spokesman for Sheffield Industry. Sir Harold was knighted for educational and industrial service in 1949. His own firm's scheme for apprentice training, which he organized, is generally acknowledged as the finest of its kind in the country.

Mr. O. M. White, M.I.E.E., A.M.I.C.E., chief engineer of Balfour, Beatty & Co., Ltd., has been appointed a director of the Company.

BUSINESS NOTES

N.A.E.S. Limited, Knoll Street, Higher Broughton, Manchester, have been appointed sole distributors in the United Kingdom for Bosch Universal Electric Tools.

A conference on **"The Operation and Maintenance of Industrial Boiler Plant"** will be held at the Grand Hotel, Harrogate, on October 21st and 22nd. There will be discussions on "The Boiler Plant—its Control and Maintenance," "The Men in the Boiler House," "The Utilisation of Waste Heat" and "Firing." The conference fee is £2 2s and attendance is open to all interested in the subjects to be discussed. Full particulars can be obtained from the Combustion Engineering Association, 6 Duke Street, London, S.W.1.

The Palliser Magnesia Works at Hartlepool have now been resold to the British Periclase Company, a subsidiary of the Steetley Co. Ltd.

The Metropolitan-Vickers Electrical Co. Ltd. and the **Edison Swan Electric Co. Ltd.** have opened new district offices at 10/12 Hospital Street, Birmingham, under the management of **Mr. A. F. Bock** for Metropolitan-Vickers and **Mr. A. H. Adey** for Ediswan.

Foire de Paris. Ninety per cent of the 125 acres space for the Paris International Trade Fair to be held in May 9th, to 25th, has already been booked. It is expected that 11,000 firms from 33 countries will be exhibiting. Applications for the remaining space should be sent to the Foire de Paris, 23 Rue N.D. des Victoires, Paris.

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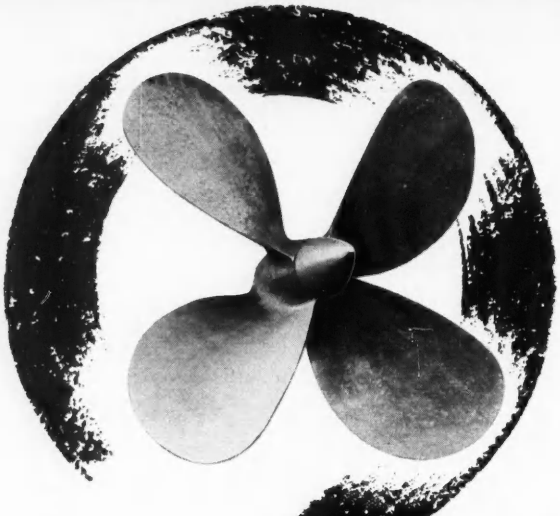

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French Production of Aluminium is expected to exceed 100,000 tons in the current year. This output compares with about 50,000 tons in 1939. Largest consumers are the transport industry with 35 per cent, the electrical industry with 24 per cent, and home appliances with more than 10 per cent.

Flying Neon Signs are the latest development in airborne advertising. They are being built by the Auster Company—which has fastened neon tubing under the wing of a light aircraft so that the wording can be seen from the ground.

Austers install special electrical equipment in the aircraft, with connections and racks so that any standard neon-tube letters can be fitted to make up the desired message.

The first of these sky-signs is on an Auster 5 recently sold to a company in Singapore.

R. A. Lister & Co. Ltd., Dursley, Gloucestershire, have concluded an agreement for the sole distribution of the Lister range of diesel engines in the United States with the National Supply Company, Springfield, Ohio, with branches in various parts of the country.

Arrangements to this effect were made following a recent visit to the United States by Sir Percy Lister, chairman of R. A. Lister & Co. Ltd., and a subsequent visit to England by F. Howard Kilberry, general manager of National Supply's Engine Division, Springfield, Ohio.

Henry Meadows Ltd., Wolverhampton, announce that the company's model 4.D.C.330 engine, which has extensive industrial, automotive and marine applications, is reduced in price by £56 to direct buyers and by £43 to manufacturers who buy at wholesale rates. Mr. E. J. Batchelor, the managing director, states that the company has a full order book at present and the reduction is due to increased productivity and reduction of overheads by reorganisation.

Ewbank & Partners Ltd., the London consulting engineers, have placed an order with **G. & J. Weir Ltd.,** Glasgow, for sea water distillation plants to provide one million gallons of fresh water per day to Kuwait, the Persian Gulf Oil State.

This is one of the largest export orders received in the West of Scotland this year. The plant will consist of ten sets of triple effect horizontal evaporators, each set with its own distilling condenser and pre-heater supplying 100,000 imperial gallons of fresh water each 24 hours. The installation will be located at Shuwaikh and the fresh water produced will be for local domestic use.

Radiovisor Parent Ltd., manufacturers of photo-electric equipment, have appointed **J. Broughton & Son (Engineers) Ltd.,** 234 Pershore Road South, Kings Norton Factory Centre, Birmingham 30, sole selling agents for their photo-electric press brake guard. All other Radiovisor products are, however, still handled by Radiovisor Parent Ltd. from their Head Office at 1 Stanhope Street, London, N.W.1.

Kerry's (Great Britain) Ltd., Warton Road, Stratford, London, E.15, has acquired controlling interest in the firm of Spare Parts Ltd., St. Peter Street, Blackburn. **Mr. W. Earnshaw** continues as director and manager of Spare Parts Ltd., and **Mr. H. Lonsdale** has retired.

British Driver-Harris Co. Ltd., Gaythorn Mill, Albion Street, Manchester 15, announce the opening of a new branch office at 27 Grey Street, Newcastle-on-Tyne. The new office will stock all types and sizes of "Drivex" cable and it will deal also with problems concerning British Driver-Harris alloys, including electrical resistance materials. The manager of the new office is **Mr. B. S. Lockett** who has held for many years an executive position at the Manchester head office of the Company.

BRITISH AIR INDUSTRY ATTACKS NEW MARKETS

With more and more emphasis being placed on British merchant aircraft exports, there is a growing interest in two new markets, Germany and Japan, where civil aviation operations are re-opening.

In the next few weeks, leading German aviation officials will be given operating details of the Viscount turboprop airliner. They will be flown in the passenger cabin and shown the flight deck of the Viscount which is making demonstration flights at major German cities. A Comet has already visited Germany and aviation officials are studying its performance with interest.

There is considerable enthusiasm for British helicopters; a Bristol Sycamore has visited Germany and the Westland Company is negotiating for an order.

In Japan, the first new aircraft to be bought when the Allied Occupation ended were British—a fleet of Auster liaison aeroplanes. A few weeks later, this was followed by a £1½ million order for long-range Comet airliners and smaller Herons for inter-island transport. Japanese airlines, like those in Germany, are also studying helicopters with interest, and the Westland Company has already received an order.

THE CRESCENT WING

British designers are actively working on a radical wing design which differs considerably from anything now flying, either swept-back or delta.

It is a crescent-shaped wing, that is, each wing is swept back from the fuselage and then, towards the tips, straightened out again.

The object of the crescent design is to take advantage of the best features of the three different types of wing which have been built for flying round the speed of sound—the delta, the swept-back wing, and the razor-thin straight wing.

Near the fuselage, the crescent wing has similar characteristics to the delta; it is swept-back about 60°, and it is broad and deep enough to house engines, fuel, undercarriage etc.

Further across the span, the wing has the less radical sweep of a normal swept-back wing, and is not so deep in relation to its width. Finally, nearer still to the tip, the wing becomes thin and almost straight—probably less than 15° of sweep.

Some designers believe that by designing the wings of large aircraft like this they may get the best of all worlds, with good structural characteristics, excellent control, and no ill-effects when the aircraft encounters "Dr. Mach."

ELECTRONIC WATCH

M. Albert Caquot, President of the French Academy of Sciences, has presented in Paris the first electronic watch. The new watch is not a laboratory curiosity but will in the not distant future come into general use.

The essential characteristic of the new watch is that an electronic energy generator has been substituted for the spring, and it will ensure normal working for at least a year, when it can easily be replaced. The power is constant the whole time, so there is no running down towards the end. And the electronic generator is smaller than a piece of confetti. The motor, although comprising a coil of 3,000 metres of insulated wire one-sixth the thickness of a human hair, requires only 1·75 millionth of a HP. The motor is the size of a baby's finger nail.

While at first the cost may be high, the electronic watch will eventually cost hardly more than an ordinary high grade watch.

RETURN OF PREMIUM GRADE PETROL

In a statement to the press commenting on the Minister of Fuel and Power's announcement that premium grade petrol will become available on the 1st February, 1953, Mr. Leonard Sinclair, Chairman and Managing Director of the Esso Petroleum Company Limited said:—

"I am naturally delighted to hear this heartening news which gives the green light to our industry. It will surely be welcomed by every motorist as making possible greatly improved performance, and more economical running, as well as by British car manufacturers in permitting the design of higher compression engines to meet competition in overseas markets.

What is perhaps of still greater significance is that the removal of this control will now enable the oil companies in Britain to put their refinery programme into full throttle and so make their maximum contribution towards the economic strength of the nation.

The precise quality and the price of the premium petrol which we shall be able to make available is now under active review. I can, however, assure motorists that they will get good value—high quality at a competitive price."

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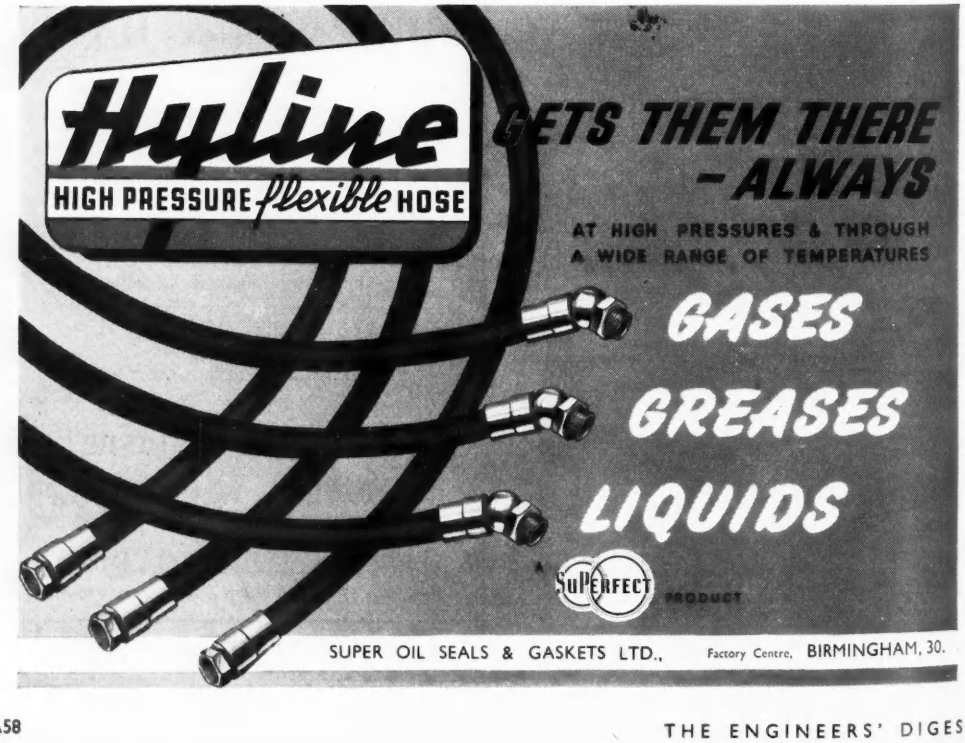

B.I.F. CHARGES

The Government are anxious that in Coronation Year the British Industries Fair should be fully representative of the commercial vitality of the country and that overseas visitors should be given a comprehensive view of the wide range of goods which British industry can supply.

It has been represented to the Board of Trade that this object would be helped if something could be done to reduce the cost of exhibiting at the Fair. The Board have gone into the matter carefully, bearing in mind their duty to prevent the organisation of the Fair becoming a charge on public funds, and have decided to reduce the charge to exhibitors for shell stands at Olympia and Earls Court by approximately 9 per cent. It is hoped that industry will take the fullest advantage of this reduction. To facilitate this the Board of Trade will continue to consider applications for space up to October 25, and the allocation of individual stands will be postponed until that date.

STUDY OF HUMAN RELATIONS IN INDUSTRY

The College of Technology, Birmingham (Principal, J. Wilson, B.Sc., B.Com., M.I.Mech.E.) has instituted a new Senior Lectureship, the first of its kind in this country. Its subject is the Human Relations aspect of Management, and it is part of the Department of Industrial Administration (Head of Dept.: D. H. Bramley). It will cover the existing courses in Psychology for Supervision, Industrial Psychology, and Personnel Administration. In addition it is hoped that some field studies can be undertaken and an advisory service set up to assist students in their personal development.

The past 15-20 years have seen some dramatic advances in production methods and the application of work-study techniques in industry. Recent impressions from the United States, however, suggest that interest is turning from these to the question of human relations at work. There is a feeling that new resources in productive efficiency might be made available through the avoidance of petty frictions at work and the achievement of wholehearted co-operation on the factory floor. A similar trend can be seen in management thought in this country, and the decision to create this new post in Birmingham is practical evidence of it. As the bulk of tomorrow's executives will be drawn from the Technical Colleges it is appropriate that students, along with their technological studies, should be encouraged to think about the human relations aspect of their jobs.

Mr. John Munro Fraser, M.A., has been appointed to this post. He is the author of two books, "Psychology, General, Industrial and Social," and "A Handbook of Employment Interviewing." For a number of years he was a senior member of the staff of the National Institute of Industrial Psychology, and for the last few months he has been a private consultant.

A NEW GROUND POWER UNIT

Crompton Parkinson Limited and Auto Diesels Limited have concluded an agreement to engage jointly in the production of mobile dual-voltage ground power units of outputs up to 95 kW for starting any class of commercial or service aircraft already in operation, under construction, or likely to be developed.

With the higher outputs now being demanded from piston, turbo-jet, and turbo-prop engines, the starting torque requirements must be met with ground units of greater capacity than before.

The Crompton Parkinson-Auto Diesels power unit is designed to give from the one generator either 112 volts or 28 volts supply. Outputs up to 850 amps at 112 volts for ten seconds, or 1500 amps at 28 volts for ten seconds may be provided.

In addition an auxiliary generator provides for servicing purposes an output of 4/6 kW at 28 volts simultaneously with a 112 volts starting supply.

Units will be available with the generator driven either by a diesel or petrol engine, or by a motor supplied from airfield mains.

With engine driven generators the maximum current output is obtained by using an engine rated to provide for the peak loading conditions without supercharging or speed boosting. In consequence, since there are no abnormal stresses on the engine it will continue to give reliable service with the minimum of maintenance.

The engine rating will provide for obtaining the maximum generator output on airfields in any climate or at any altitude throughout the world.

For emergency purposes, e.g. lack of engine fuel etc., the equipment includes batteries giving 96 volts and 24 volts respectively. These batteries are normally charged from the generator of the unit.

The switchgear for controlling the 112 volts and the 28 volts outputs incorporates protective features that prevent operators damaging the unit or aircraft in the event of incorrect switching.

All instruments are of the new long circular scale pattern, developed recently by Crompton Parkinson Limited, and have open scales over the working range so that they can be read at a glance from some distance away. The instruments incorporate resilient mountings to ensure continued accuracy under conditions of shock and vibration.

Equipment is incorporated to eliminate radio interference. Compactness of the power unit has been achieved by using an engine with a favourable power/weight ratio and a single dual-voltage generator instead of two separate generators.

The 4/6 kW auxiliary generator is separately mounted and belt driven from the front of the engine.

The power unit is mounted on a four-wheeled trailer with a low centre of gravity so as to avoid any danger of over-turning under certain airfield conditions. The chassis is of all-welded construction.

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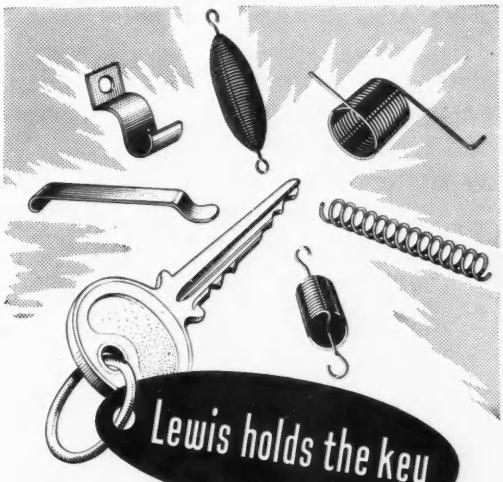

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BRITISH STANDARDS

(Copies of British Standards may be obtained from the British Standards Institution, 24, Victoria Street, London, S.W.1)

Terms and Definitions for Single-Point Cutting Tools. B.S. 1886 : 1952 has been prepared with the assistance, among others, of representatives of the British Hard Metal Association and the Welded and Brazed High Speed Steel Tool Trade Association, and, after presenting definitions of various types of single-point tools, proceeds to deal with rakes, working angles, clearance angles, tool elements and general terms.

The definition of rake has received special attention and, as a result, it is laid down that the Maximum Rake System shall be the British Standard method of defining rake, as distinct from the German or American systems.

A number of sketches and diagrams serve to assist and clarify the textual definitions, and the tool and production man will find the Appendix of interest.

The appendix is devoted to extracts from Dr. Galloway's book "Standardization and Practical Application of Cutting Tool Nomenclature" published by the Institution of Production Engineers. The extracts, on a method for the conversion of rake angles, have been slightly amended where necessary to bring them into line with the Maximum Rake System nomenclature. The standard concludes with the introduction of the Rake conversion chart from the work quoted above. Price 6/-.

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ADMIRALTY. Vacancies exist for Civil Engineers (Main Grade) in the Civil Engineer-in-Chief's Department, Pinner, Middlesex. Starting salary £950 per annum. Duties cover Headquarters Administration of Civil Engineering programme. Temporary appointments. Minimum age 40. Applicants must be natural born British subjects and corporate members of the Institution of Civil Engineers, Administration experience essential. Application forms quoting E 149/52/A from Ministry of Labour and National Service, Technical and Scientific Register (K), Almack House, 26, King Street, London, S.W.1.

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